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MATERIAL SELECTIONS FOR ELASTOMERIC SEALS IN THE REACTOR REFUELING SYSTEM OF THE CRBRP

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ABSTRACT

This report recommends elastomer compounds and manufacturers for each elastomer seal in the reactor refueling system of the CRBRP (System 41).

This report discusses:

- Techniques for data acquisition
- Elastomer material review
- Seal leakage calculations
- Basis for elastomer selections.

The basic recommendations are to:

- Use Buna N elastomers for seal applications when service temperatures permit satisfactory life
- Use EPDM (ethylene propylene rubber) in sealing applications where operational temperatures are too high for Buna N
- Avoid use of silicone elastomer due to its extremely high permeation rate
- Use metallic O-ring seals only where longer service life is desired than may be obtained with an elastomer.

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1.0 INTRODUCTION

The purpose of this report is to make material selections of the elastomeric seals for the reactor refueling system (System 41) of the CRBRP. This work was performed in 1976 and reflects the status of the design at that time.

The goal of these selections is to optimize properties to obtain minimum seal leakage with maximum seal life.

This report discusses:

- The methods and logic on which seal material selections were made and that form a basis for future selections
- The actual data and materials selected for the seals of System 41.

The logic/method discussion considers:

- Techniques for data acquisition (Section 4.0)
- Properties of elastomer material (Section 5.0)
- Seal leakage calculations (Section 6.0)
- Bases for the elastomer selection (Section 7.0).

The actual elastomer selections are found in the appendix.

Material selection of inflatable seals has not been performed at this time, due to current status of development, design, and manufacturing of the inflatable seal. To perform a proper material selection, these areas must first be resolved for the material selection to have maximum reliability.

The selections within this report are based on design data gathered from preliminary and conceptual designs. Final design may alter some of the locations and other design parameters. If this should occur, the guidelines established within Section 1.0 should be followed to verify and/or establish proper material selection.

It is desirable to standardize seal sizes whenever possible. Sufficient data to make such standardization are present in the appendix. The function of this report is not to standardize seal sizes. It is recommended that the data presented be used at a future time to make standardizations.

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2.0 CONCLUSIONS

The following conclusions were reached:

- The parametric study on seal leakage[13] indicated that by proper elastomer material selection, the "tentative" leakage criteria may be satisfied.
- Selections of actual seals are based on preliminary and conceptual designs. Sealing networks may change before final designs are complete. Therefore, verification of satisfactory seal selection may be required at the completion of final design.
- Leakage studies have not been performed on all equipment of System 41. They may be required on selected additional equipment before the end of final design.
- In the selection process, to best meet sealing and life requirements for the variety of service conditions, leakage/permeation and seal life were regarded as primary criteria for selection, although other properties were also considered.
- Seal selections are often based on compromise solutions after consideration of available property data and known or estimated service requirements.

The general order of preference for selection is:

- Buna N (nitrile)
- Ethylene propylene (EPDM or EPR)
- Silicone.

Commercial compounds listed in this report appear adequate for the applications studied. Material developments from compound improvement and new technology should be monitored to ensure the availability of most effective seal materials and the development of supporting data.

The appendix presents application details and seal recommendations in tabular form for convenient reference.

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3.0 RECOMMENDATIONS

This report recommends elastomer compounds and manufacturers for each seal in System 41. The basic recommendations are to:

- Use Buna N (nitrile) elastomer for seal applications when service temperatures are low enough and satisfactory life may be obtained.
- Use EPDM (ethylene propylene rubber) in sealing applications where operational temperatures are too high for Buna N to obtain satisfactory service life.
- Avoid use of silicon elastomer due to its excessively high permeation rate.
- Use metallic O-ring seals only when operational temperatures are too high for elastomer seals or longer service life is desired than may be obtained with elastomer seals.

Specific recommendations in line with above are given in the appendix.

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4.0 DATA ACQUISITION TECHNIQUES

To select the proper seal material required having all pertinent design information and knowing the conditions that would affect the seal material. A review of elastomeric and sealing properties indicates the necessity of knowing the following:

- External effects
  - Temperature
    - Hypothetical accident temperatures
    - Normal operational temperatures
    - Time at temperature
    - Number of cycles
  - Atmosphere
    - Media
    - Pressure
  - Radiation dose rate/total dose
    - Hypothetical accident conditions
    - Normal conditions
- Design criteria
  - Seal type and application
  - Nominal diameter and cross-section diameter
  - Gland dimensions and surface finishes
  - Nominal compression
  - Leakage path
  - Normal service life
  - Desirable service life.

Since System 41 is large and complex, a chart format was used to record all the data (see the appendix). In some cases, the desired data were unavailable. For these situations, the assigned place on the chart was left blank or an acceptable estimate was made.

The gathered data are felt to offer a sufficient base on which material selection can be made.

5.0 ELASTOMERIC MATERIAL REVIEW

5.1 INTRODUCTION

Considerable work has been done at AI to establish various elastomer types of interest for use as static and dynamic seals for CRBRP applications.[1,2] This work has involved evaluating a variety of specific industrial compounds, and considerable data from suppliers as well as AI laboratories have been developed.

One aim of this study is to select from the variety of materials available the type most suitable for the majority of System 41 applications, thereby permitting standardization of materials and obtaining attendant benefits resulting from such optimization of compound selection.

All potential elastomer types were considered. Those selected, based on properties and testing at AI, are listed in Table 1. The properties of those compounds are shown in Table 2. These are typical values from the manufacturers, which permits comparison of materials.

TABLE 1
POTENTIAL ELASTOMERS

Vendor	Compound Number			Seal Type(s)
	Buna N	EPDM (EPR)	Silicone	
Parker Seal	N 741-75	E 692-75	S 684-70	O-Ring Q-Ring T-Ring
Minnesota Rubber	366Y-70	559 N-70	71417-70	O-Ring Q-Ring
Greene Tweed	969-70	952-85	407-85	T-Ring

TABLE 2

PROPERTIES OF ELASTOMERS[a]

Property	ASTM Test Method	Buna N			EPDM (EPR)				Silicone		
		N 741-75 (Parker)	366Y-70 (Minne-sota)	969-70 (Greene Tweed)	E 529-65 (Parker)	E 692-75 (Parker)	559 N-70 (Minne-sota)	952-85 (Greene Tweed)	S 684-70 (Parker)	71417-70 (Minne-sota)	407-85 (Greene Tweed)
Tensile strength (psi)	D-412	2440	2035	1980	2160	1560	1800	2111	1200	1095	790
Hardness, durometer "A"	D-2240	71	70	73	64	73	70	85	73	70	84
Elongation (%)	D-412	210	325	-	332	218	325	-	232	165	250
Tear strength (psi)	D-624	218	-	153	218	191	-	65	179	75	82
Specific gravity		1.20	1.24	1.23	1.25	1.15	1.16	1.18	1.23	1.43	1.26
<u>Air Age</u>	D-573										
Number of hours		70	70	70	70	70	70	70	70	24	70
Temperature (°F)		257	212	392	302	302	212	392	347	437	392
Hardness, pts (change, pts)		75 (+4)	-	(+20)	68 (+4)	83 (+10)	(-2.5)	(+11)	75 (+2)	(+7)	(+2)
Tensile strength, psi (change %)		2370 (-3)	(+3)	(-57)	2070 (-4)	1720 (+10)	(+5)	(-96)	1300 (+8)	(-9.7)	(-1.6)
Elongation % (change %)		169 (-20)	(-20)	(-94)	358 (+8)	208 (-5)	(-13.6)	(-97)	250 (+8)	(-15.9)	(-7.2)
<u>Compression Set</u>	D-395 (25% comp.)										
Number of hours		22	22	22	22	22	70	70	22	22	22
Temperature (°F)		158	212	158	158	158	212	158	158	347	-
% of original deflection		3.2	8.4	7.8	8.7	9.6	17.0	5.7	3.2	12.3	8.8
<u>Abrasion Resistance, Tabor</u>	D-1044										
Weight loss (mg/1000 cycles)		8.1	-	-	9.2	13.6	-	-	8.1	-	-
<u>Resilience, Bayshore</u>	D-2362										
% rebound		17	-	58	48	46	-	63	17	-	65

[a]Manufacturers' typical properties.

5.2 SEAL SELECTION CRITERIA

Elastomer seal selection is based on a combination of physical, chemical, and mechanical factors for development of a reliable seal with suitable service life. Factors of good seal design are extremely important, but beyond the scope of this report. To achieve desired seal chracteristics, seal materials must have a combination of the following factors:

- Suitable temperature/life properties
- Suitable resilience (compression set resistance) characteristics to retain sealing qualities during desired life
- Low permeability to reactor cover gas(es)
- Resistance to gamma radiation levels anticipated in service
- Compatibility with seal lubricants, service environments (gases, Na vapor, etc.).

In these considerations, a life of 5 years between maintenance cycles (seal replacement) has been the goal. The above factors are briefly discussed below.

5.2.1 Temperature/Life Properties and Suitable Resilience

The various elastomers considered have characteristic temperature capabilities based on structure and compounding. Figure 1 presents a general comparison of temperature limits for several elastomers.

This chart cannot be used for precise predictions of seal life, but it does give a comparison of elastomer thermal properties. Temperature-time curves show the safe cumulative time at a given temperature for elastomers used as static seals. For dynamic applications, temperatures as much as 25°F below those indicated may be more realistic.

AI has done considerable work in estimating seal useful life. Compression set data have been plotted on Arrhenius-type plots in an attempt to predict the maximum temperature corresponding to a 5-year life.[1] In that work,

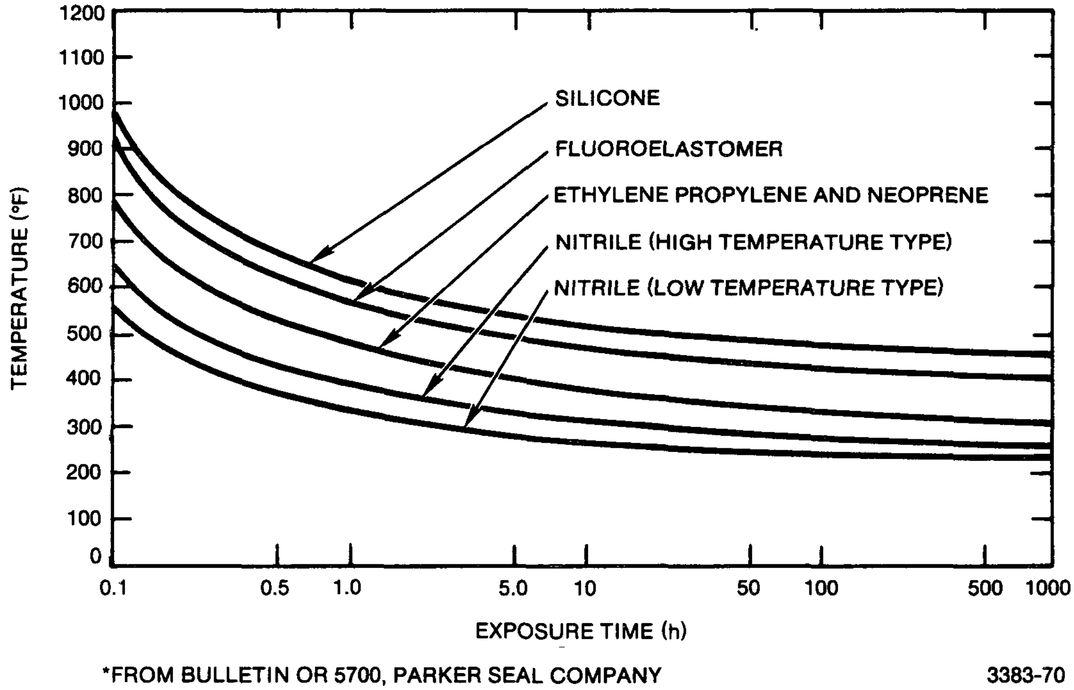

Figure 1. Seal Life at Temperature
(data from Bulletin OR 5700, Parker Seal Company)

cracking of the N714-75 Buna N compound at temperatures of 150 and 200°F after 2 weeks' exposure was noted.[1] Tests conducted on Parker's N219-70 indicated a service temperature of 106°F, corresponding to a 5-year life with compound N219 at 90% compression.

Discussions with Parker's technical staff verified Buna N compound N219 to be a "general purpose" compound, superseded in September 1973 by their N674-70, the latter showing overall superiority and specifically significantly superior compression set resistance. Compression set resistance is the property of primary importance for seal longevity.

Concurrently, compound N741-75 was developed to reflect compounding improvement due to availability of new and improved materials and techniques and to provide the maximum in high-temperature oil and compression set resistance.

Further, on a theoretical basis, compound N741 should possess greatly superior compression set (and other) properties than N219. The former is a peroxide-cured compound, possessing the inherently greater stability of carbon-to-carbon bonding, while the latter (N219) is a sulfur-cured compound, possessing the weaker bonding characteristic of this curing system. Additionally, the approximately 50% compression of materials used in AI's compression testing is approaching the limit (normally around 60%), usually contributing to stress cracking of rubbers. Very likely, the five point higher hardness of N741 over N219 (75 versus 70 durometer "A") was also a contributing factor.

At any rate, Parker's N741-75 Buna N is an improved compound with remarkably superior thermal and compression set resistance (over both N219 and N674). Thus, the limiting 5-year life temperature of 106°F imposed by the N219 compound is considered lower than that obtainable by using a high thermal resistance, low compression set compound such as N741-75.

Figures 2 and 3 present comparisons of compression set at 25% internal compression (a range more like the optimum for O-ring static seals) for the series of Buna N (nitrile) compounds discussed.[3-5] The superiority of Parker's N741-75 over the other Parker compounds is evident.

Table 3 presents further corroboration of this compound's improved properties.

The type of seal usage (e.g., static, dynamic, temperature cycling) has an important bearing on performance. The limiting compression set the seal can tolerate and still function depends on this usage. Figures 4 through 6 present estimated lives and corresponding temperatures for compression sets of 70, 80, and 90%.[1] In a static seal not exposed to thermal cycling, sets higher than 90% (conceivably approaching 100%) could continue to give satisfactory results, since one major cause of failure in elastomeric seals is thermal cycling. The combination of thermal expansion and stress relaxation act to greatly reduce seal contact stress during thermal cycling.

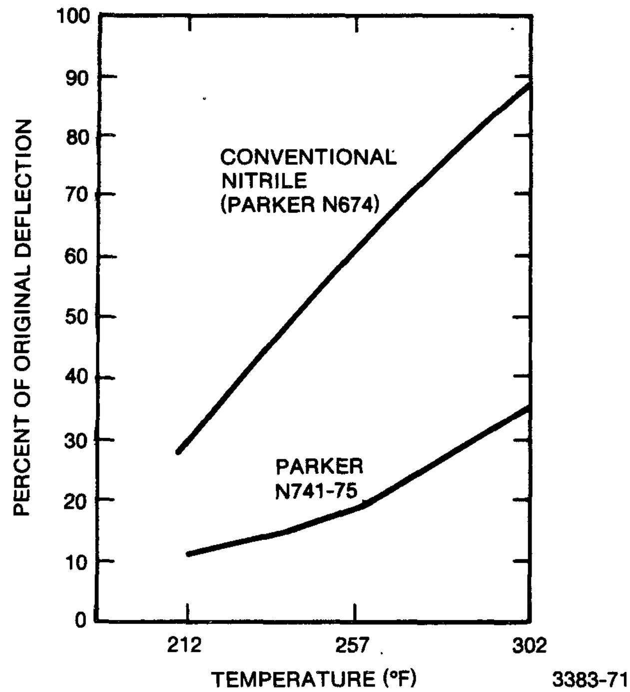

Figure 2. Compression Set,
ASTM D-395 Method B
(25% constant deflection,
70 h at temperature)

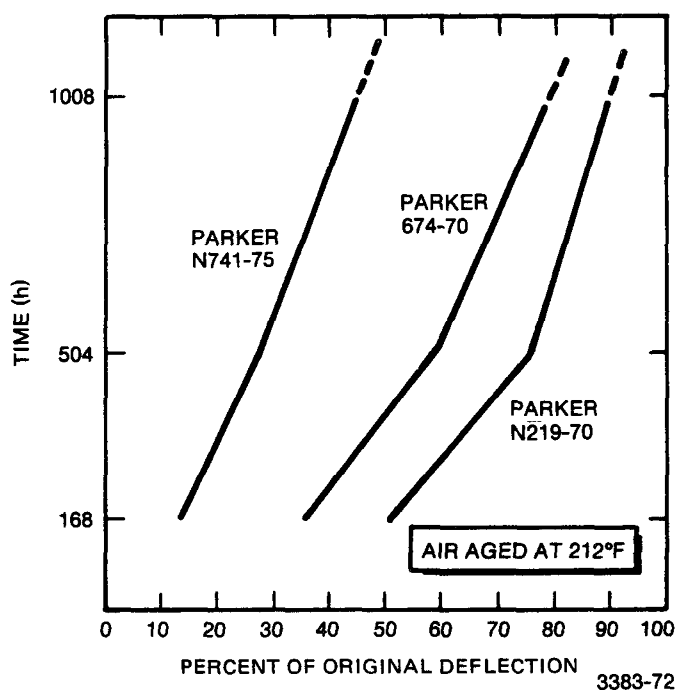

Figure 3. Compression Set, Percent of
Original Deflection
(ASTM D-395, 25% deflection

TABLE 3

COMPARISON OF PARKER BUNA N COMPOUNDS

Property	Test Condition	Compound		
		N219-70	N674-70	N741-75
	Original Properties			
Hardness, durometer "A"		73[a]	68[a]	76[b]
Tensile (psi)		2064	2363	2250
Elongation (%)		279	300	135
Modulus at 100% elongation (psi)		455	634	1300
Specific gravity			1.23	1.21
	168 h/212°F			
Hardness (change, pts)		80 (+7)	75 (+7)	82 (+6)[c]
Tensile, psi (change %)		2199 (+6.5)	2416 (+2.2)	
Elongation (change %)		244 (-19.7)	210 (-30.0)	
Modulus (change %)		840 (+84)	944 (+48.9)	
Compression set, 25% deflection, % of original draft		50.4	35.9	17 (extr)
	504 h/212°F			
Hardness (change, pts)		84 (+11)	84 (+11)	77 (+9)
Tensile, psi (change %)		2283 (+15.5)	2283 (+15.5)	2265 (-4.2)
Elongation (change %)		174 (-37.5)	174 (-37.5)	163 (-46.7)
Modulus (change %)		1186 (+160.7)	1186 (+160.7)	1455 (+129.5)
Compression set, 25% deflection, % of original draft		76.2	58.5	29 (extr)
Compression set, 25% deflection, % of original deflection (ASTM D-395)	70 h/212°F			11
	70 h/257°F		35[d]	18[e]
	70 h/302°F			35
	1000 h/212°F	89	78	46

[a] Reference 4
[b] Reference 3
[c] 70 h/257°F
[d] Reference 6
[e] Reference 5

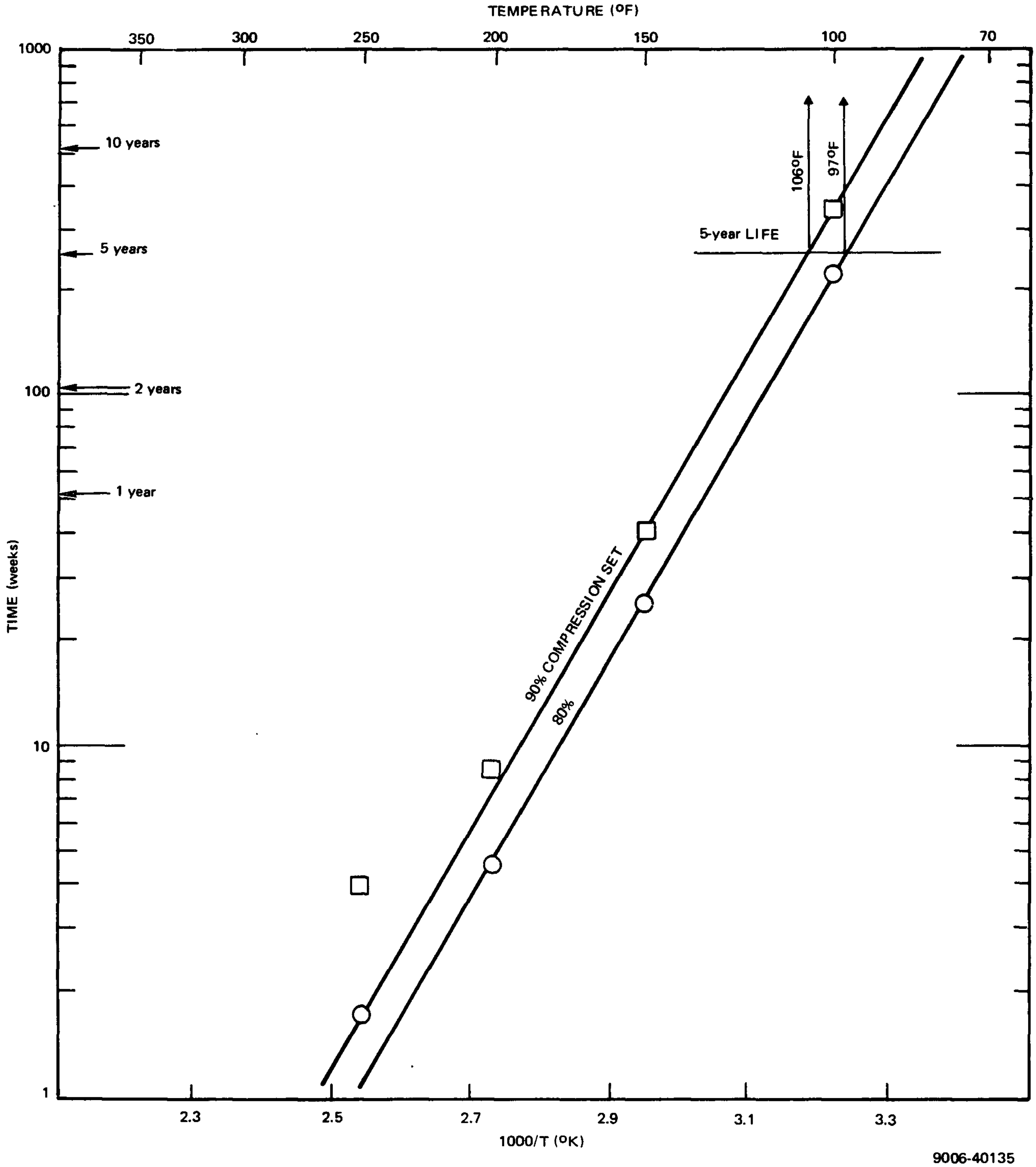

Figure 4. Estimation of Seal Useful Life at 80 and 90% Compression Set (Parker O-ring seal, Buna N, compound N219)

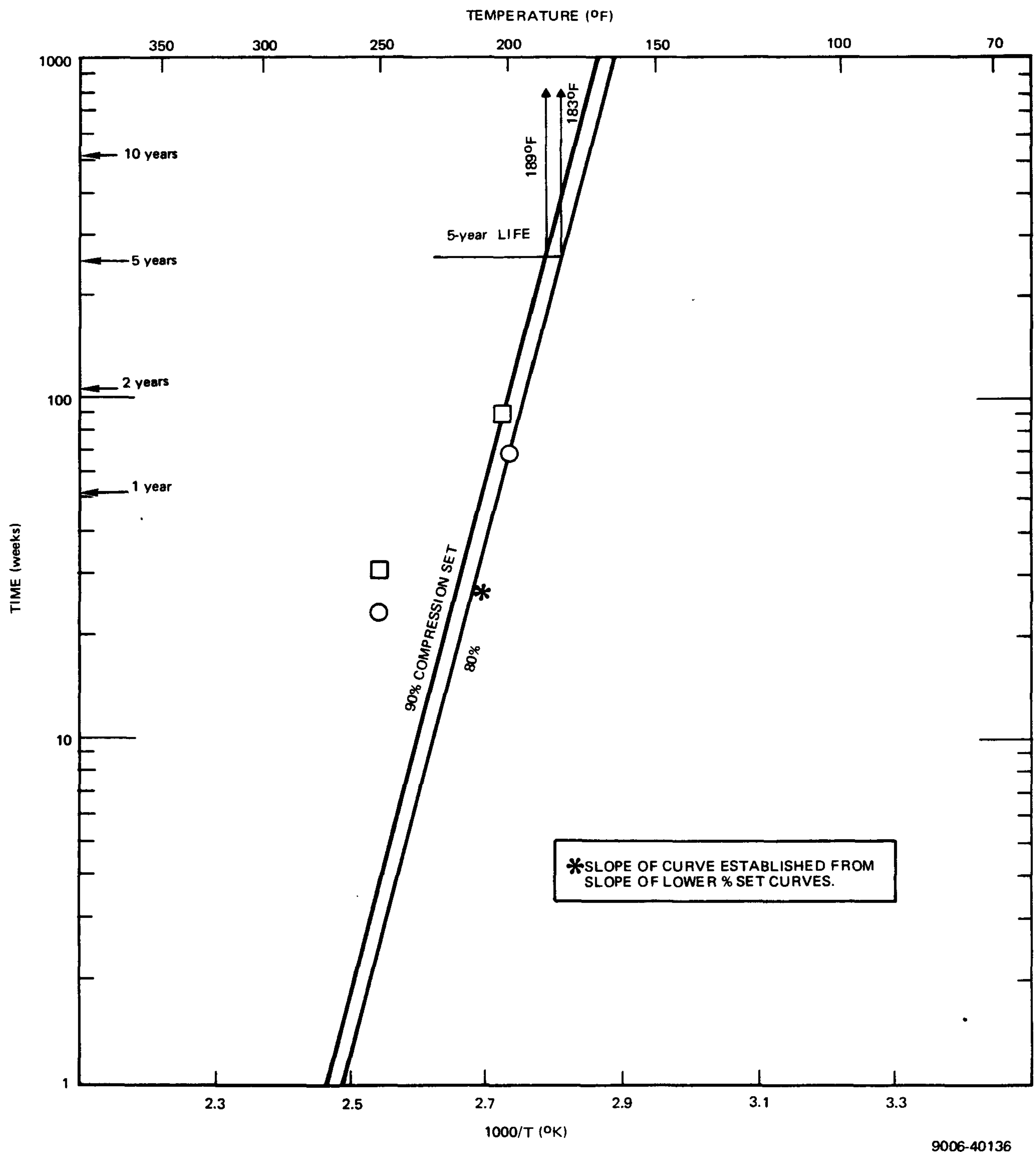

Figure 5. Estimation of Seal Useful Life at 80 and 90% Compression Set (Parker O-ring seal, ethylene propylene, compound E692)

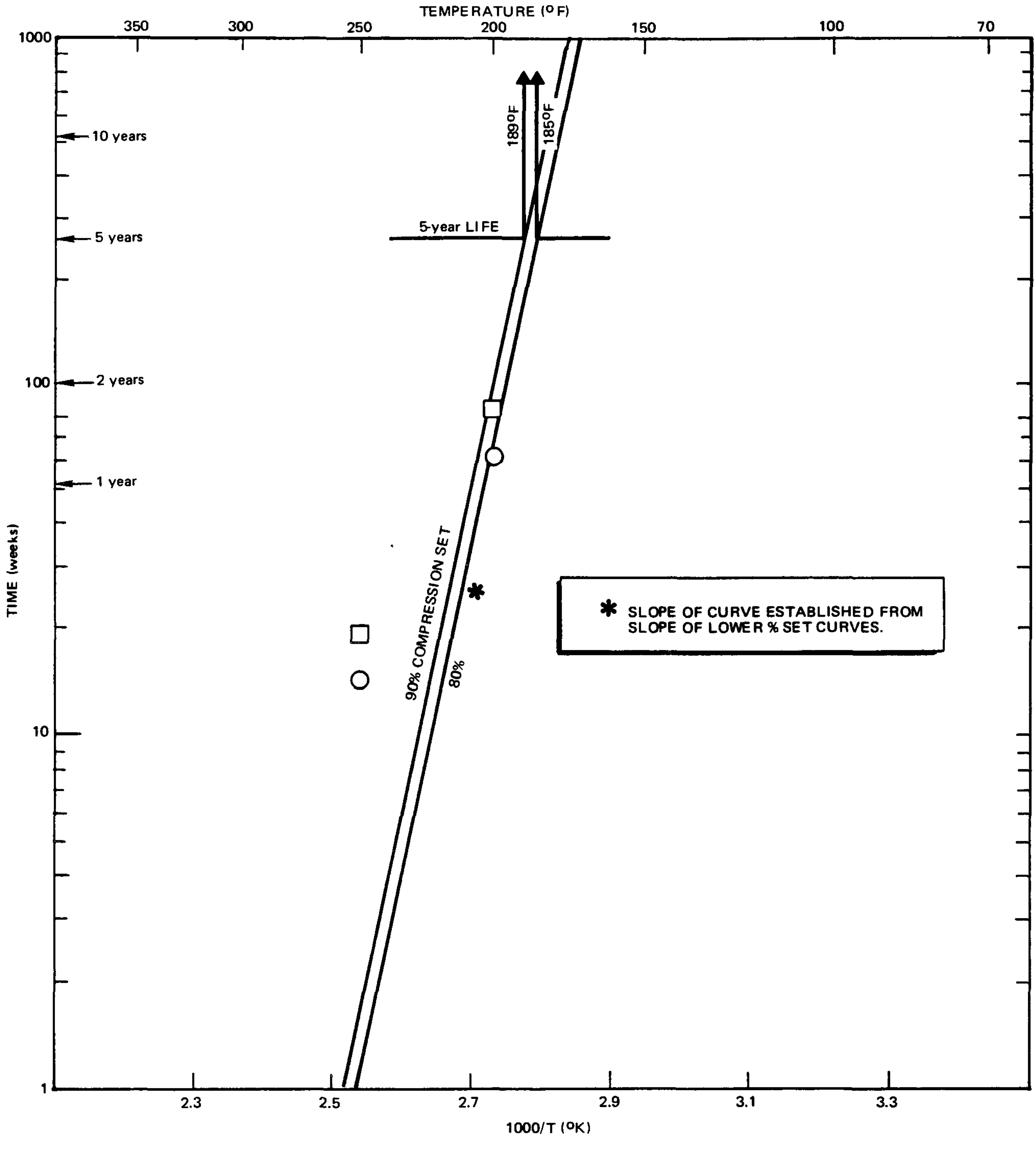

Figure 6. Estimation of Seal Useful Life at 80 and 90% Compression Set (Parker O-ring seal, silicone, compound S684)

As temperature rises, the rubber expands and stress increases, even though strain is constant. When temperature is held constant, stress relaxes. When temperature is reduced, the rubber contracts to the worst case; contraction can reduce stress to zero.

Expansion coefficients of elastomers and common material of interest are listed below.

Elastomer	Linear Coefficient of Expansion (in./in. per °F)
Nitrile (Buna N)	6.2×10^{-5}
Ethylene propylene	8.9×10^{-5}
Silicone	10.0×10^{-5}
Stainless steel (304 SS)	9.6×10^{-6}
Steel, mild	6.7×10^{-6}

Various available compression set data were incorporated with data produced by AI on compound N219.[1] These are shown in Figure 7. Although incomplete and made on different bases (54% initial compression for N219 versus 25% for N674 and N741), all data confirm the overall superiority of Buna N (N741), which should offer an estimated 25 to 50°F advantage in thermal/life capability. This estimation might well be subject to confirmation by test, in view of the desirability of using the Buna N type seal as widely as practical, due to its low permeability to gases of interest. Such confirmatory testing should be performed in the method of ASTM D-395, Method B (constant deflection at 25% initial deflection) to more closely approximate use conditions and not overstress the rubber.

A. J. Court[7] analyzed compression set data from 1000-h lifetime vendor tests, usually at 25% compression, and longer term lifetime data obtained in the Cover Gas Seal Program as 50% compression. In many cases, reaction rate expressions were found to fit the data, and service lifetimes to 1% recovery (99% compression set) were predicted from the 50% compression data of selected temperatures. These are summarized in Table 4, and the maximum operating temperatures for a 5-year service life at 50% compression are also included.

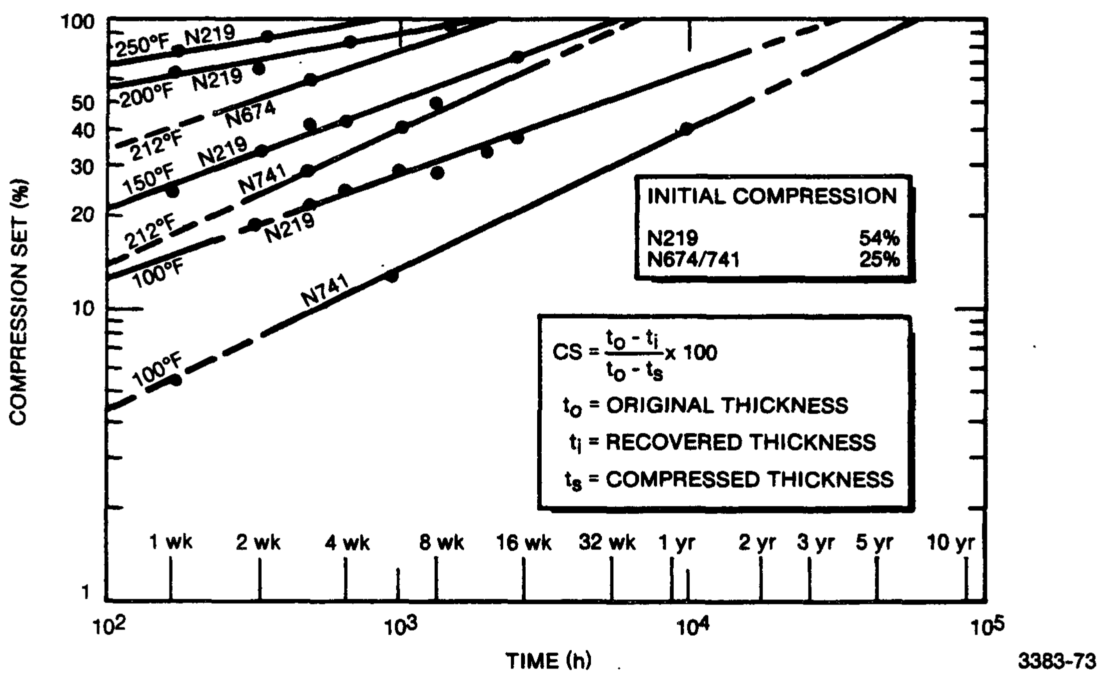

Figure 7. Compression Set Comparison of Parker Buna N Compounds N219, N674, and N741

TABLE 4

EFFECT OF TEMPERATURE ON RECOVERY FOR SPECIFIC ELASTOMER FORMULATIONS AT 50% COMPRESSION

Temperature (°F)	Buna N			Ethylene Propylene (EPDM)			Silicone	
	N741	366Y	N219	E692	E529	559N	S684	71417
250	-	-	-	0.53	0.43	1.0	0.56	3.1
200	a	2.6	0.31	2.2	3.4	1.7	2.9	33+
150	a	4.7	2.0	5.8	19.0	-	15	-
100	58	24	6	16.0	-	-	98	-
Maximum continuous operating temperature for a 5-year life[b]		154	107	166	188		180	

[a]Cracked in 4 weeks
[b]End of life = 1% recovery.

If the 50% compression test data demonstrate lifetime at the expected operating temperature, then the lifetime at 5 to 30% compression will be extended because the lighter squeeze minimizes thermal degradation of the seal. Although the potential increase in service life may be predicted, and should be proportional to known or measured thermal and compression set properties of the elastomers considered, the only reliable way to predict life is to test the specific formulation at the temperature and squeeze of the actual application.

5.2.2 Low Permeability to Reactor Cover Gas(es)

Permeability, the tendency of a gas to diffuse through the elastomer, is a different mechanism than mechanical leakage around the seal. The permeability of an elastomeric barrier to a given gas depends first on the rate at which the gas dissolves into the elastomer surface, and then on the rate at which it diffuses through the elastomer. Permeability varies not only with polymer type, but also with compounding ingredients and copolymer proportions.

AI laboratories have made specific determinations on the elastomers of interest.[1] Tables 5, 6, and 7 compare permeabilities for Buna N, ethylene propylene, and silicone rubbers. The order of increasing permeability is Buna N, ethylene propylene, silicone; the relative differences between rubbers are large.

5.2.3 Radiation Resistance[7,8]

The anticipated use of elastomeric seals in CRBRP applications places new requirements on rubber compounds. Although the mechanism of radiation damage to elastomers is not completely understood, it is generally accepted that ionization is the predominant factor that changes rubber properties. Displacement of atoms caused by energy absorption from incident particles and electromagnetic radiation brings about changes that are chemical in nature. Ions or free radicals are formed, with resulting polymerization, crosslinking, discoloration, dehydrogeneration--with eventual cracking and degradation. Although

TABLE 5

COMPARISON OF PERMEABILITY ($\overline{P}$) OF BUNA N (NITRILE) RUBBERS

Gas	Vendor	$\overline{P}$ (scc•cm/s•cm^2•cm Hg ΔP x 10^{-9})			
		Temperature (°F)			
		100	150	200	250
H_2	Green Tweed[a]	1.44	4.0	9.6	21.8
	Minnesota Rubber[b]	2.0	5.0	10.5	21.2
	Parker Seal[c]	1.49	3.5	7.2	14.1
Ar	Green Tweed	0.15	0.47	1.3	3.1
	Minnesota Rubber	0.50	1.25	2.6	5.2
	Parker Seal	0.25	0.54	1.0	1.8
Kr	Green Tweed	0.13	0.57	2.0	6.1
	Minnesota Rubber	0.39	1.45	4.7	13.2
	Parker Seal	0.37	0.90	1.9	3.6
Xe	Green Tweed	0.14	0.69	2.6	8.8
	Minnesota Rubber	0.47	1.75	5.2	13.4
	Parker Seal	0.43	1.1	2.4	4.9

[a]Green Tweed compound 969
[b]Minnesota Rubber compound 366Y
[c]Parker Seal compound N741

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TABLE 6

COMPARISON OF PERMEABILITY ($\bar{P}$) OF ETHYLENE PROPYLENE RUBBERS

Gas	Vendor	$\bar{P}$ (scc·cm/s·cm^2·cm Hg ΔP x 10^{-9}) Temperature (°F) 100	150	200	250	300
H_2	Green Tweed[a]	3.9	9.8	21	39	68
	Minnesota Rubber[b]	8.3	18	34	43	100
	Parker Seal[c]	6.4	14	28	47	80
Ar	Green Tweed	1.5	3.4	6.8	12	21
	Minnesota Rubber	2.6	6.1	12	22	40
	Parker Seal	2.2	5.2	11	20	36
Kr	Green Tweed	2.3	5.7	12	23	42
	Minnesota Rubber	3.3	7.3	15	26	46
	Parker Seal	2.5	5.8	12	22	28
Xe	Green Tweed	1.8	4.6	10	20	36
	Minnesota Rubber	5.4	12	24	42	74
	Parker Seal	5.1	11	21	37	62

[a] Green Tweed compound 969
[b] Minnesota Rubber compound 366Y
[c] Parker Seal compound N741

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TABLE 7

COMPARISON OF PERMEABILITY ($\overline{P}$) OF SILICONE RUBBERS

Gas	Vendor	$\overline{P}$ ($scc \cdot cm/s \cdot cm^2 \cdot cm\ Hg\ \Delta P \times 10^{-9}$)				
		Temperature (°F)				
		100	150	200	250	300
H_2	Green Tweed[a]	72	170	325	580	980
	Minnesota Rubber[b]	42	110	245	490	910
	Parker Seal[c]	120	210	275	380	500
Ar	Green Tweed	34	76	150	245	440
	Minnesota Rubber	58	90	130	175	230
	Parker Seal	45	57	69	82	94
Kr	Green Tweed	92	115	140	160	185
	Minnesota Rubber	64	110	175	260	370
	Parker Seal	97	130	170	210	260
Xe	Green Tweed	14	58	183	470	1440
	Minnesota Rubber	95	135	185	230	285
	Parker Seal	163	195	230	260	295

[a]Green Tweed compound 969
[b]Minnesota Rubber compound 366Y
[c]Parker Seal compound N741

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upgrading changes can occur under controlled radiation dosage, long exposure usually causes degrading effects with loss of properties.

The degree of change depends on several factors, including rate of radiation, irradiation time, energy of the radiation, material composition, environment (stress, temperature, pressure, atmosphere, etc.), initial state (often associated with the history of the material), and type of radiation.

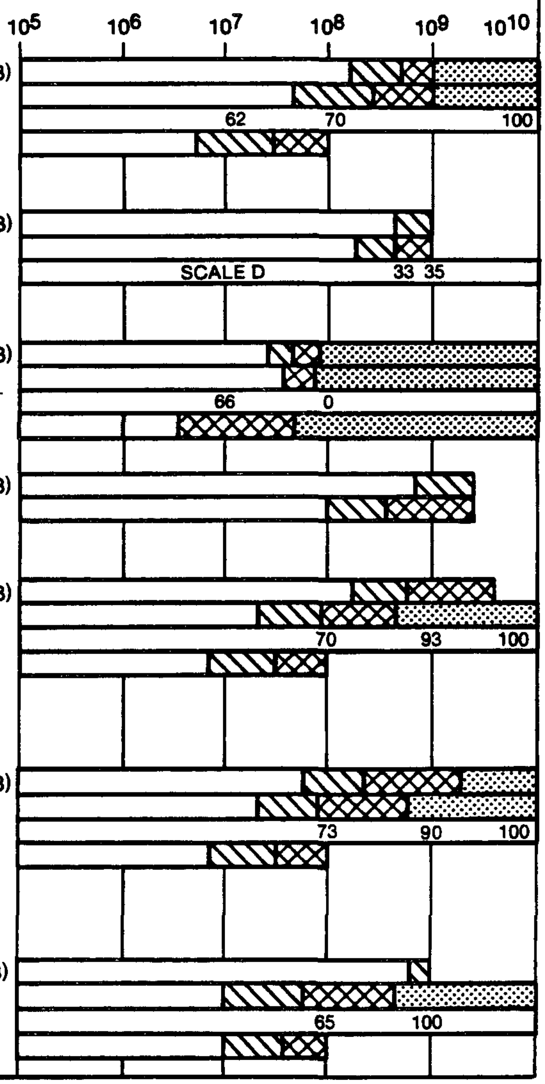
In this study, the radiation resistance of candidate seal elastomers was one of the criteria used for selection. Anticipated radiation environments in System 41 seal applications were studied, and seal materials were assessed for their suitability.

Figure 8 provides a general comparison of how elastomer properties are affected by gamma radiation. This type of rating scale should be regarded as general in nature because of the relative comparisons shown, and the difficulty of ranking different classes of materials as well as differences (due to compounding, processing, etc.) of materials in the same class. Also, it is necessary to take as many properties into account as possible to best study the behavior and effects of materials to radiation. This is particularly true for applications that do not require holding property changes to a minimum. For example, a substantial loss in elongation will not affect the utility of many types of seals.

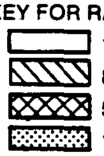
Limited data are available on specific seal compounds of interest. Table 8 presents these data (obtained from one manufacturer),[9-11] which indicate the relative degrees of radiation resistance of materials. From these data as well as consideration of general elastomer characteristics shown in Figure 8, the Buna N, EPDM, and silicone materials would appear usable in gamma radiation levels of approximately 10^8 rads at ambient temperature. Higher temperature would cause corresponding reductions in radiation use levels; the reduction due to the combined effect is not necessarily additive.

MATERIAL	INITIAL[b,d,e] VALUE	
HYDROCARBON RUBBERS		
NATURAL RUBBER		
TENSILE STRENGTH (psi)	2600	(3)
ELONGATION AT BREAK (%)	420	
SHORE HARDNESS, SCALE A	60	
COMPRESSION SET, RECOVERY (%)	93	
ETHYLENE PROPYLENE RUBBER (EPR)		
TENSILE STRENGTH (psi)	1320	(13)
ELONGATION AT BREAK (%)	275	
SHORE HARDNESS, SCALE A	97	
BUTYL RUBBER GR-150		
TENSILE STRENGTH (psi)	1100	(3)
ELONGATION AT BREAK (%)	525	
SHORE HARDNESS, SCALE A	66	
COMPRESSION SET, RECOVERY (%)	91	
BUTADIENE RUBBER		
TENSILE STRENGTH (psi)	2380	(13)
ELONGATION AT BREAK (%)	525	
STYRENE-BUTADIENE RUBBER (SBR) (GRS-50)		
TENSILE STRENGTH (psi)	1700	(3)
ELONGATION AT BREAK (%)	270	
SHORE HARDNESS, SCALE A	62	
COMPRESSION SET, RECOVERY (%)	90	
OXYGEN-CONTAINING RUBBERS		
POLYACRYLIC RUBBER HYCAR PA-21		
TENSILE STRENGTH (psi)	2000	(3)
ELONGATION AT BREAK (%)	230	
SHORE HARDNESS, SCALE A	62	
COMPRESSION SET, RECOVERY (%)	92	
NITROGEN-CONTAINING RUBBERS		
NITRILE RUBBER HYCAR OR-15		
TENSILE STRENGTH (psi)	1900	(3)
ELONGATION AT BREAK (%)	250	
SHORE HARDNESS, SCALE A	72	
COMPRESSION SET, RECOVERY (%)	92	

PERCENT OF INITIAL VALUE RETAINED AT GIVEN DOSE (rads)[a,c]



[a]KEY FOR RADIATION EFFECTS:



100 TO 80% OF INITIAL VALUE RETAINED
80 TO 50% OF INITIAL VALUE RETAINED
50 TO 10% OF INITIAL VALUE RETAINED
10 TO 0% OF INITIAL VALUE RETAINED

[b]TO CONVERT lb/in.^{2} TO kg/mm^2, DIVIDE BY 1422 SO THAT 14,220 lb/in.^{2} EQUALS 10 kg/mm^2

[c]RAD EQUALS 100 ergs/gram OF SAMPLE MATERIAL

[d]SHORE DUROMETER HARDNESS, DESCRIBED IN ASTM-D676-19T

[e]COMPRESSION SET, DESCRIBED IN ASTM-D395-49T

3383-74

Figure 8. Effects of Radiation on Rubbers (Taken from Ref. 8)

TABLE 8

EFFECT OF GAMMA RADIATION ON ELASTOMER PROPERTIES[a]
(Sheet 1 of 2)

Compound	Tensile Strength (psi)	Elongation (%)	Hardness (Duro "A")	Compression Set, RT (%) Method B, 27% Deflection	Compression Set, RT (%) Method B, 25% Deflection
Buna N					
N741-75					
Original	2440	210	70	2.9	
10^6 rads	-	-	-	5.7	
10^7 rads	-	-	-	24.3	
10^8 rads	-	-	-	71.4	
N674-70					
Original	2363	300	68	4.3	
10^6 rads	-	-	-	-	
10^7 rads	-	-	-	17.1	
10^8 rads	-	-	-	70.0	
Ethylene Propylene					
E529-65					
Original	2160	332	64		-
10^7 rads	-	-	-		-
E692-75					
Original	1560	218	73		-
10^7 rads	-	-	-		-
E740-75					
Original	2080	233	70		6.7
10^6 rads	-	-	-		9.7
10^7 rads	2140	194	73		28.6
10^8 rads	1700	86	79		84.7
10^9 rads	-	-	-		98.1

TABLE 8

EFFECT OF GAMMA RADIATION ON ELASTOMER PROPERTIES[a]
(Sheet 2 of 2)

Compound	Tensile Strength (psi)	Elongation (%)	Hardness (Duro "A")	Compression Set, RT (%)	
				Method B, 27% Deflection	Method B, 25% Deflection
Ethylene Propylene (Continued)					
E515-80					
Original	1450	213	78		16.2
10^6 rads	-	-	-		-
10^7 rads	1220	176	78		46.6
10^8 rads	1030	79	84		96.2
10^9 rads	-	-	-		95.3
Silicone					
S604-70					
Original	1010	149	64		3.8
10^7 rads	1020	129	-		20.0
10^8 rads	938	31	73		9015
10^9 rads	-	-	-		104.7
S684-70					
Original	1200	165	73		
10^7 rads	-	-	70		
10^8 rads	-	-	-		
10^9 rads	-	-	-		

[a]Data from Parker Seal, Minnesota Rubber Company.

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5.2.4 Compatibility with Seal Lubricants

The use of a lubricant in all seal applications has been recommended,[1,2] with a thin coating of the proper type providing appreciable friction reduction and increased life, even at low levels of initial compression. Lubricants tested to date have been grease types, selected for proper lubricity and rubber compatibility. "Internally lubricated" rubber components (those not requiring external lubricant application) have been developed and are also being considered.

Elastomer-lubricant use combinations are

- DC55M (Dow Corning): A silicone-based grease for use with Buna N and EPDM elastomers
- Exxon 5182 (Exxon Corp.): A diester-based grease for use with Buna N, EPDM, and silicone elastomers.

DC55M is preferred in dynamic seal applications, providing lower starting friction after long dwell times. DC55M causes swell and softening of silicone rubber; Exxon 5182 should be used with this type.

5.2.5 Chemical Compatibility with System Construction Materials

The possibility was anticipated of elastomer scission or reaction (by contact with sodium, sodium vapor, etc.), thereby liberating certain ions capable of detrimental response with system materials of construction. To avoid this possibility, guidelines for elastomer selection included the following compositional requirements:

- No halogens, cadmium, or mercury
- 0.25% maximum chloride as impurity
- 0.05% maximum lead.

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6.0 SEAL LEAKAGE CALCULATIONS

The prime purpose of seals used in System 41 of the CRBRP is to prevent radioactive gases from escaping from the system into the building and beyond. Unfortunately, seals are not perfect and they permit small amounts of gases to pass through and around them.

To examine this problem and evaluate the radioactive level reached within the building created by this leakage, a parametric study was performed.[12] This report was based on the assumption that mechanical leakage (i.e., leakage around the seal) does not occur and that leakage is solely due to permeation through the elastomeric seals. This would be assured in practice by periodic testing to detect mechanical leakage.

The technique employed to evaluate the leakage of seals is new and unique. It investigates the transitory levels of radioactivity. The technique accounts for the radioactive decay and hold times as the gases permeate through the elastomeric seals.

6.1 TYPES OF SEALS EVALUATED

Three basic types of seal construction were evaluated within System 41:

- Solid cross-section elastomeric seals
- Inflatable elastomeric seals
- Metallic seals.

6.1.1 Solid-Cross-Section Elastomeric Seals

This type of seal is the most numerous within System 41. The most common forms (Figure 9) that are members of this category are

- O-ring
- T-seal
- Quad ring.

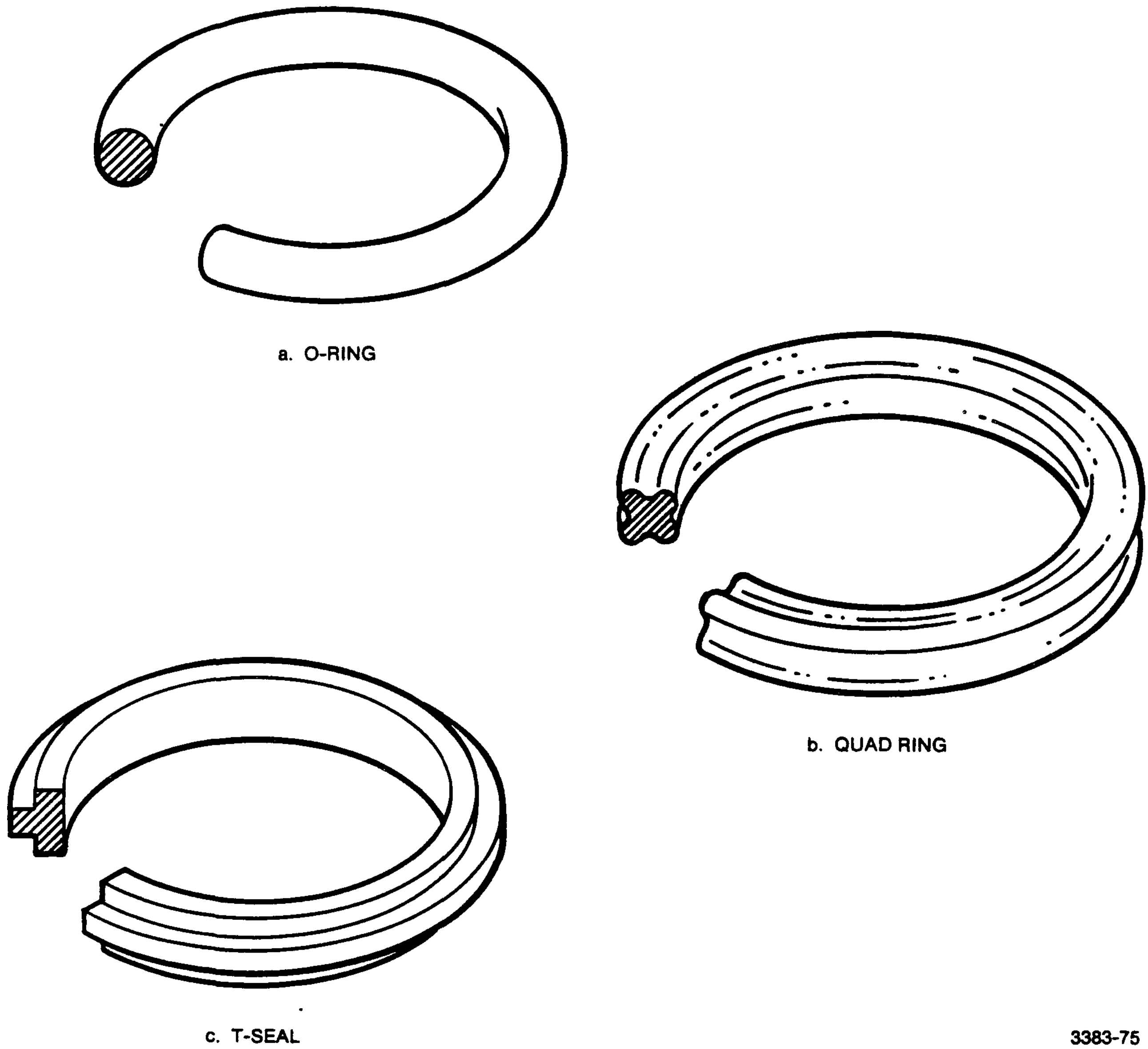

Figure 9. Solid Cross Section of Elastomeric Seals

The parametric study found very little leakage/permeability data available for T-seals or quad rings. To circumvent this difficulty, it used as a close approximation permeation data for O-rings. Tests have determined that permeation/leakage data of O-rings approach permeation data of elastomeric slab material.[13]

6.1.2 Inflatable Elastomeric Seals

An inflatable seal is an elastomeric seal that may be pressurized from the interior to cause the seal to increase its size and create a sealing surface (Figure 10). The seal, very similar to a bicycle inner tube, is made of a laminated elastomer and fabric with a ridge surface attached to the top to form a sealing bead.

The report[12] indicates that, under ideal conditions (i.e., with no leakage around the seal), inflatable seals are the single largest leakage contributor. In addition, there was great difficulty in obtaining seals that met design specifications.

Due to these difficulties and the exceptionally high permeability of the current design of inflatable seals, no material selection will be made at this time. An improper material selection at this time could create problems in perfecting the design by placing it under undue constraints. The current concerns for inflatable seals and AI's approach to their solution are presented in Table 9.

6.1.3 Metallic Seals

For System 41, metallic seals infer metal O-rings. Under ideal conditions, metal O-rings have the lowest permeation/leakage rate of the three major types. This is due to essentially no permeation of gases through the metal and very little mechanical leakage by "perfect" sealing faces. The parametric leakage calculations have assumed ideal conditions and based their data on very limited testing of metal seals.

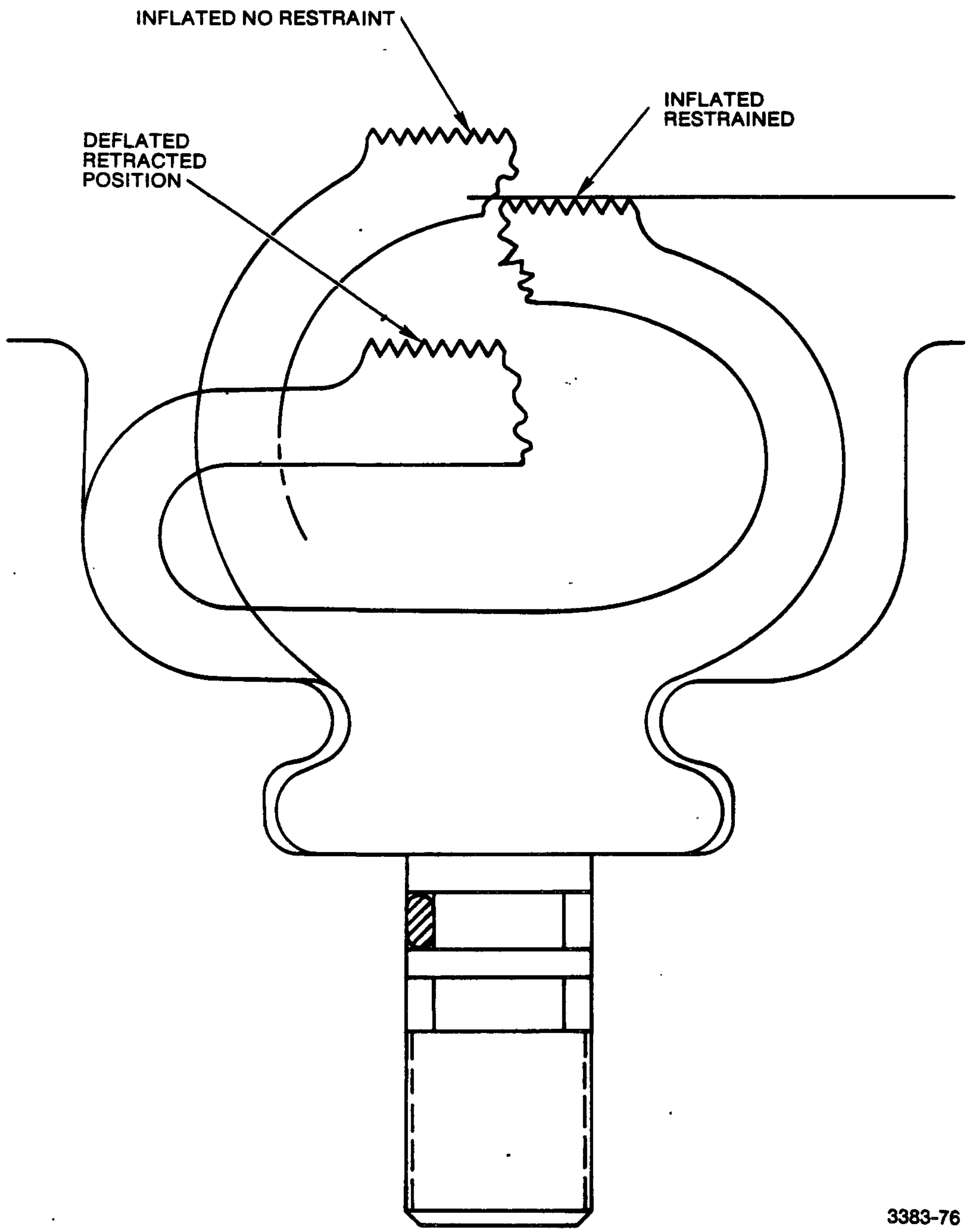

Figure 10. Inflatable Seal

TABLE 9

CONCERNS AND SOLUTIONS FOR INFLATABLE SEALS

Concern	Approach for Solution
Due to manufacturer's lack of experience with the nuclear industry's requirement, difficulty exists in obtaining seals that satisfy the specifications.	AI is working with suppliers to upgrade seal quality and improve their understanding of the unique requirements of the nuclear industry.
There is a need to standardize on an optimum cross-section configuration.	AI is analyzing seal usage conditions and is working with seal manufacturers to design an optimum inflatable seal which may be used for most static applications. The current dynamic seal design is acceptable.
Difficulty has occurred with the reproducibility of the polymers. Reproducibility is necessary to assure that all seals will have equal mechanical response.	The manufacturer will be required to supply records assuring that all seals are manufactured from the same batch and cure date. The manufacturer will be required to perform standard ASTM tests to verify consistency of mechanical and physical properties.
The thermal degradation (long- and short-term) characteristics of the elastomer are not well defined.	Compounding studies are being conducted to upgrade knowledge of commercial and experimental materials.
There is a lack of knowledge surrounding the selection of the fabric reinforcement material.	Investigations about the high-temperature properties of fabrics are being conducted. The possibilities of a steel fabric are being reviewed.
It is desirable to minimize the permeation gases through the inflatable seal.	Use of foil permeation barriers is being considered.
More knowledge of irradiation damage on the functioning of the inflatable seal is needed.	Tests evaluating irradiation effects are planned to access the failure limits.

Under realistic conditions, it is the most difficult to achieve ideal sealing surfaces with metal O-rings. Therefore, leakage calculations of metallic O-rings are subject to some suspicion, yet present calculations are the best available.

6.2 UNITS OF "LEAKAGE" AND DESIGN CRITERIA

To understand the results of the study, it is necessary to understand the units of measurement and the "tentative" acceptance criteria.

The units of leakage measurement are fractional-maximum permissible concentration (FR-MPC) of a specific radioactive isotope or mixture of specific radioactive isotopes. The definition of the maximum permissible concentration (MPC)[14] is an average radiation dose of 0.25 mrem/h for an area having full-time occupancy; larger doses are permissible for short durations.

The CRBRP has decided to limit the permissible radioactive exposure in continuously occupied areas to 0.2 mrem/h.[14] They have also suggested that the maximum exposure due to radioactive gas leakage be limited to 10% of this value, i.e., 0.02 mrem/h.

Since this exposure is the cumulative summation of all "leaks" in the building, each source must be assigned its contribution. The precise contribution for each source has not yet been determined. For the purpose of this parametric study, 10% of the total exposure, or 0.002 mrem/h, was assigned each to both the EVTM and EVST. Thus, the normal FR-MPC for the two units is approximately 10^{-3} FR-MPC. Similar criteria were used to assign the IVTM a FR-MPC of 3×10^{-2} under normal conditions. The previous FR-MPCs are only suggestions and have not been officially accepted; they are subject to change at any time.

6.3 NORMAL AND ACCIDENT OPERATION

The upper normal limit for radioactivity within the interiors of the system is defined as 1% burst fuel pins in a fuel assembly. This is approximately two failed pins.

The definition of the maximum accident condition is the radioactivity caused by the bursting of an entire fuel assembly (217 fuel pins).

The FR-MPC limits established for normal operation do not apply for the more severe accident conditions. The FR-MPC limits for the maximum accident have not been established at this time.

6.4 PARAMETRIC STUDY RESULTS

Figures 11 through 20 give results from the parametric study and show the important calculations. The study has studied the case where all seals in the system are of one material.

Figure 11 shows that a finite time is required to reach the maximum FR-MPC. Systems totally of EPR and Buna N will satisfy the suggested leakage criteria because they are always below the 10^{-3} FR-MPC. Silicone will not satisfy this limit.

Figure 12 establishes that Xe-133 will be the primary radioactive source within the system. Therefore, all other isotopes created during a fuel assembly rupture will be neglected. The study also established, but the figure does not show, that FR-MPC has a linear relationship with the percentage of ruptured fuel pins.

Figure 13 establishes that as the purification rate of CAPS is increased, there is a decrease in peak FR-MPC.

Figure 14 establishes that as RSB vent rate is increased, there is a decrease in peak FR-MPC.

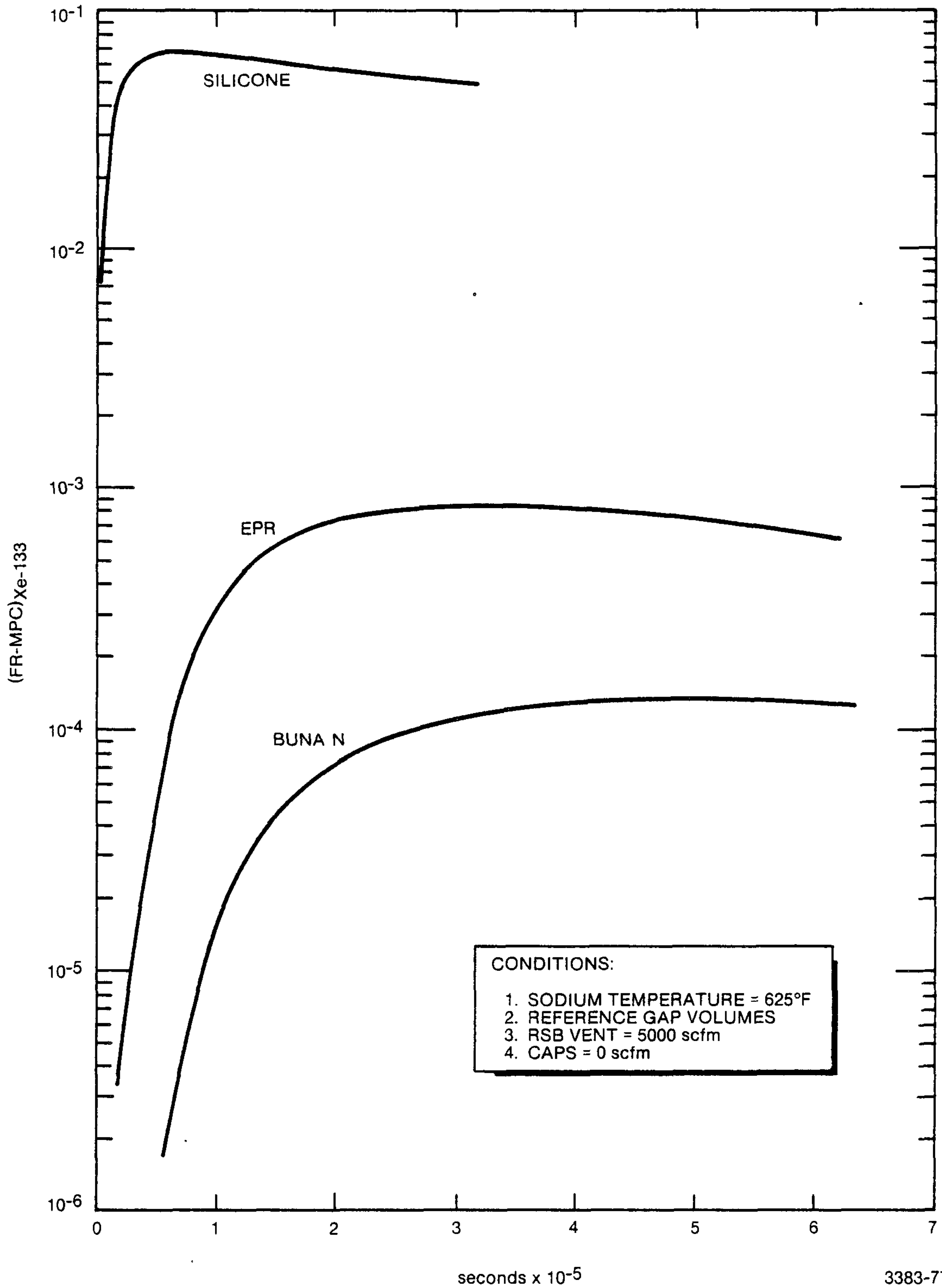

Figure 11. Effect of Elastomer Material on Xe-133 Leakage from EVST with Two Closed Floor Valves for Two Burst Fuel Pins

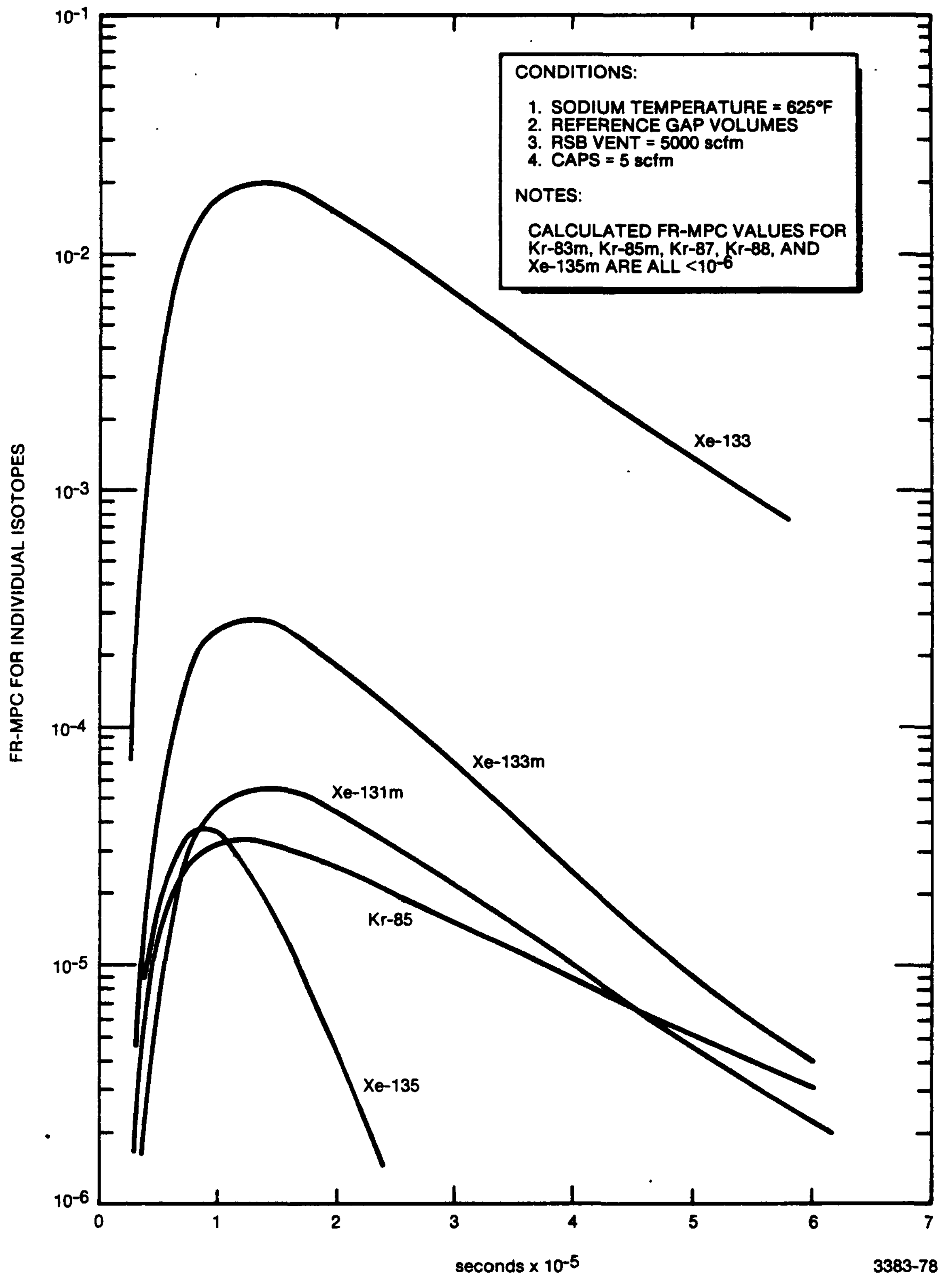

Figure 12. Xenon and Krypton Isotope Leakages Utilizing EPR Equivalent Seal for EVST with Two Closed Floor Valves for Burst of an Entire Fuel Assembly

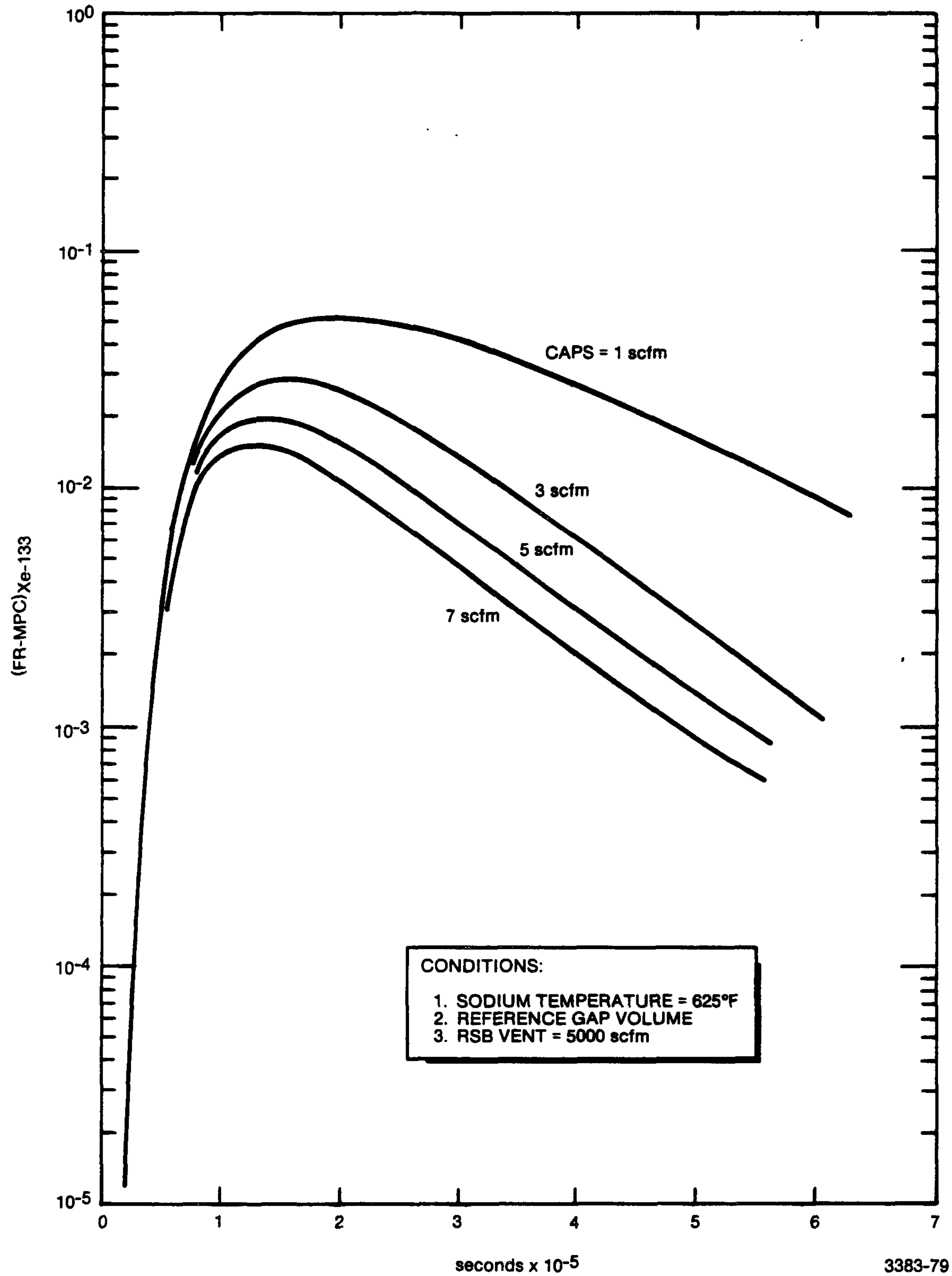

Figure 13. Parametric Study Utilizing EPR Equivalent Seal for EVST to Indicate Effect of CAPS Rate on Xe-133 Leakage for Burst of an Entire Fuel Assembly

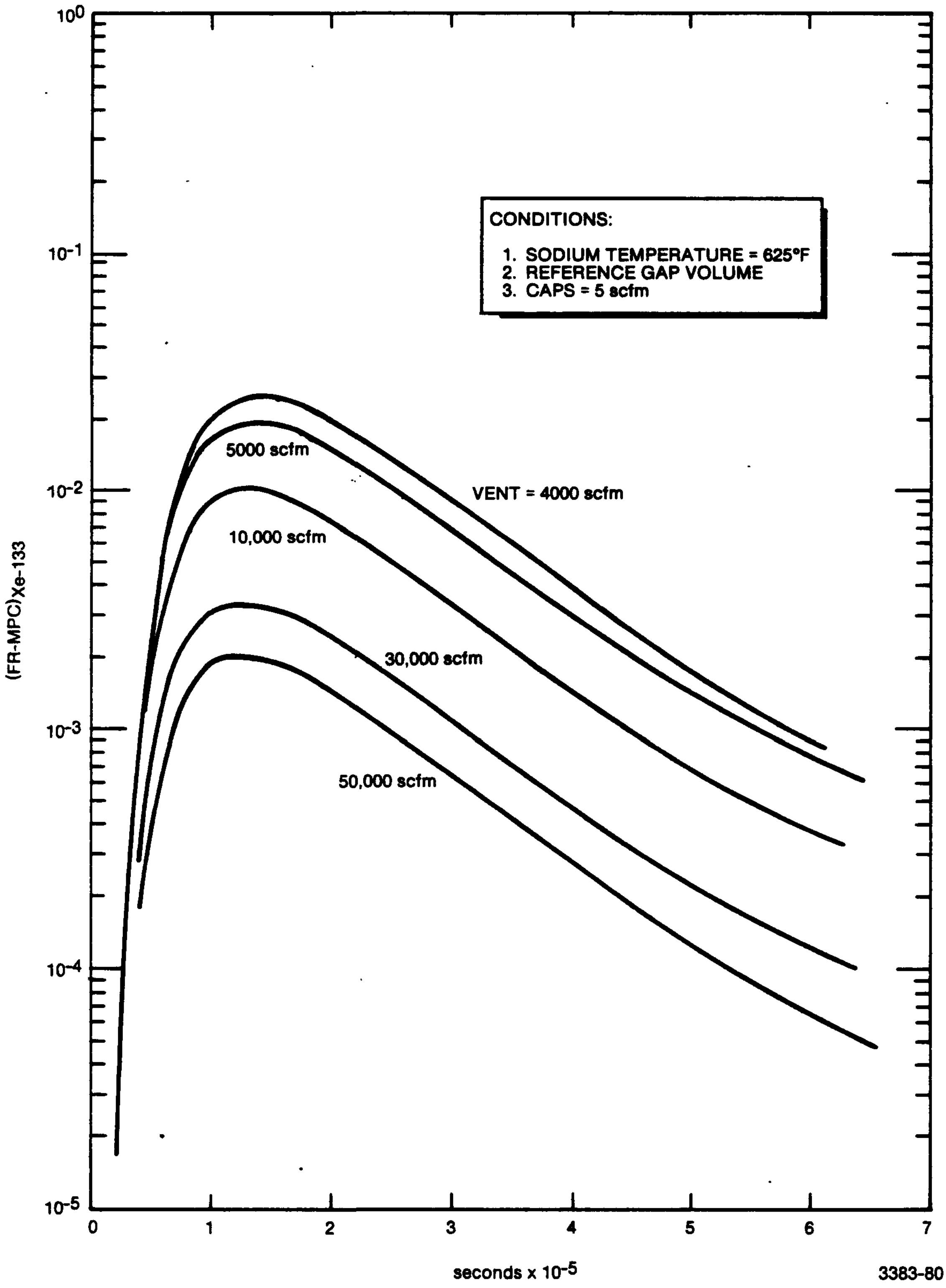

Figure 14. Parametric Study Utilizing EPR Equivalent Seal for EVST to Indicate Effect of RSB Vent Rate on Xe-133 Leakage for Burst of an Entire Fuel Assembly

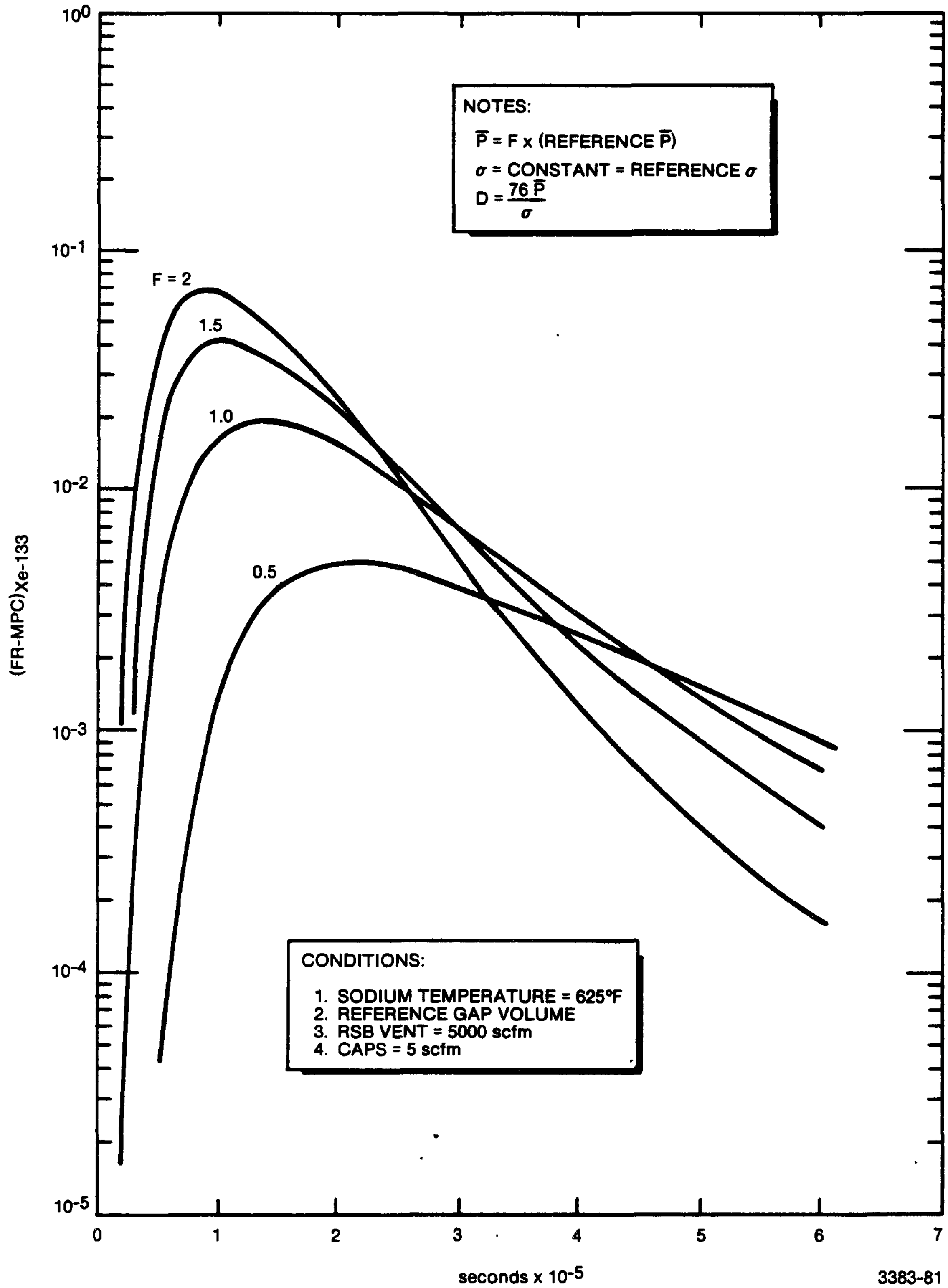

Figure 15. Parametric Study Utilizing EPR Equivalent Seal for EVST to Indicate Effect of Permeability on Xe-133 Leakage for Burst of an Entire Fuel Assembly

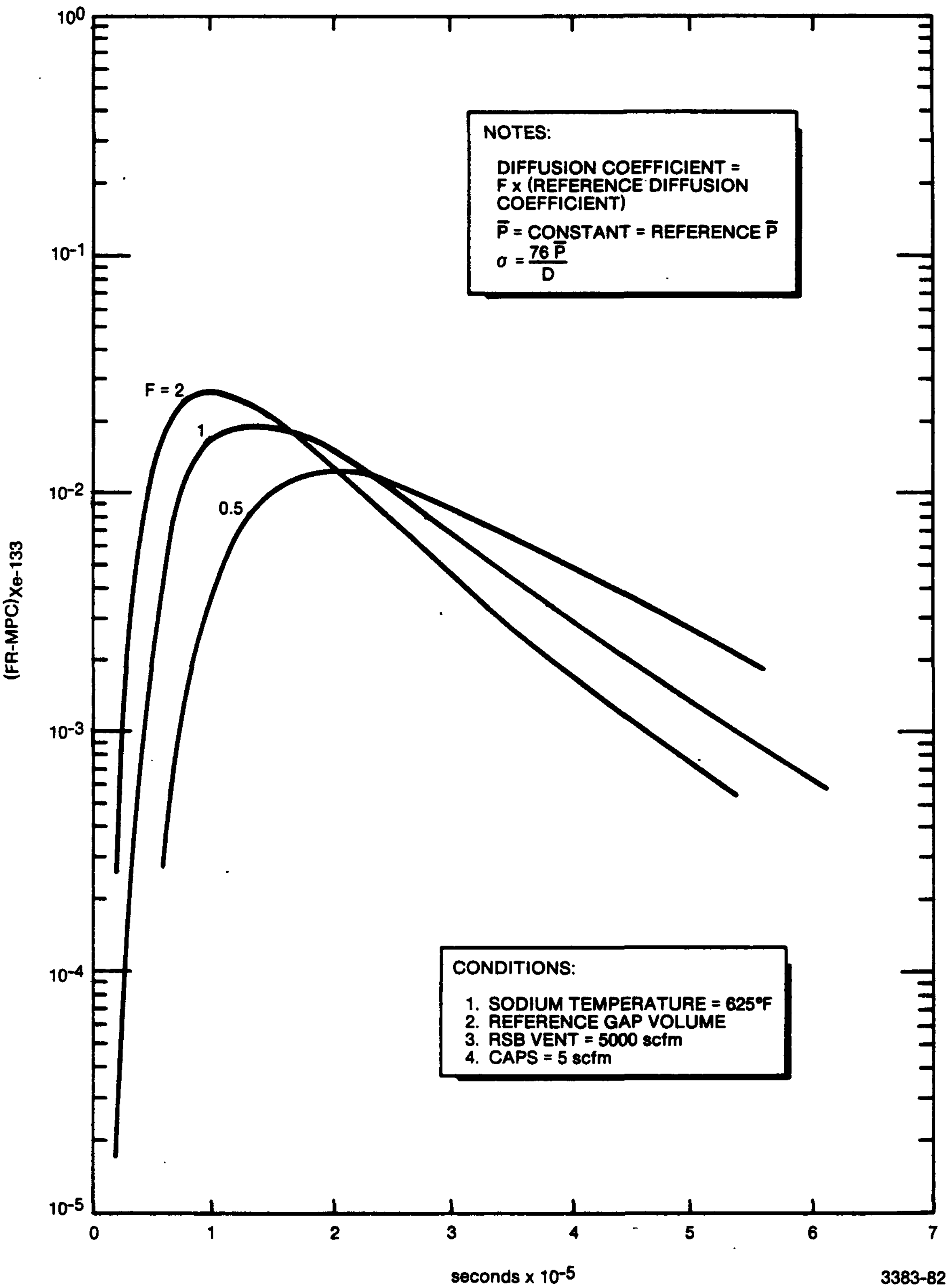

Figure 16. Parametric Study Utilizing EPR Equivalent Seal for EVST to Indicate Effect of Diffusion Coefficient on Xe-133 Leakage for Burst of an Entire Fuel Assembly

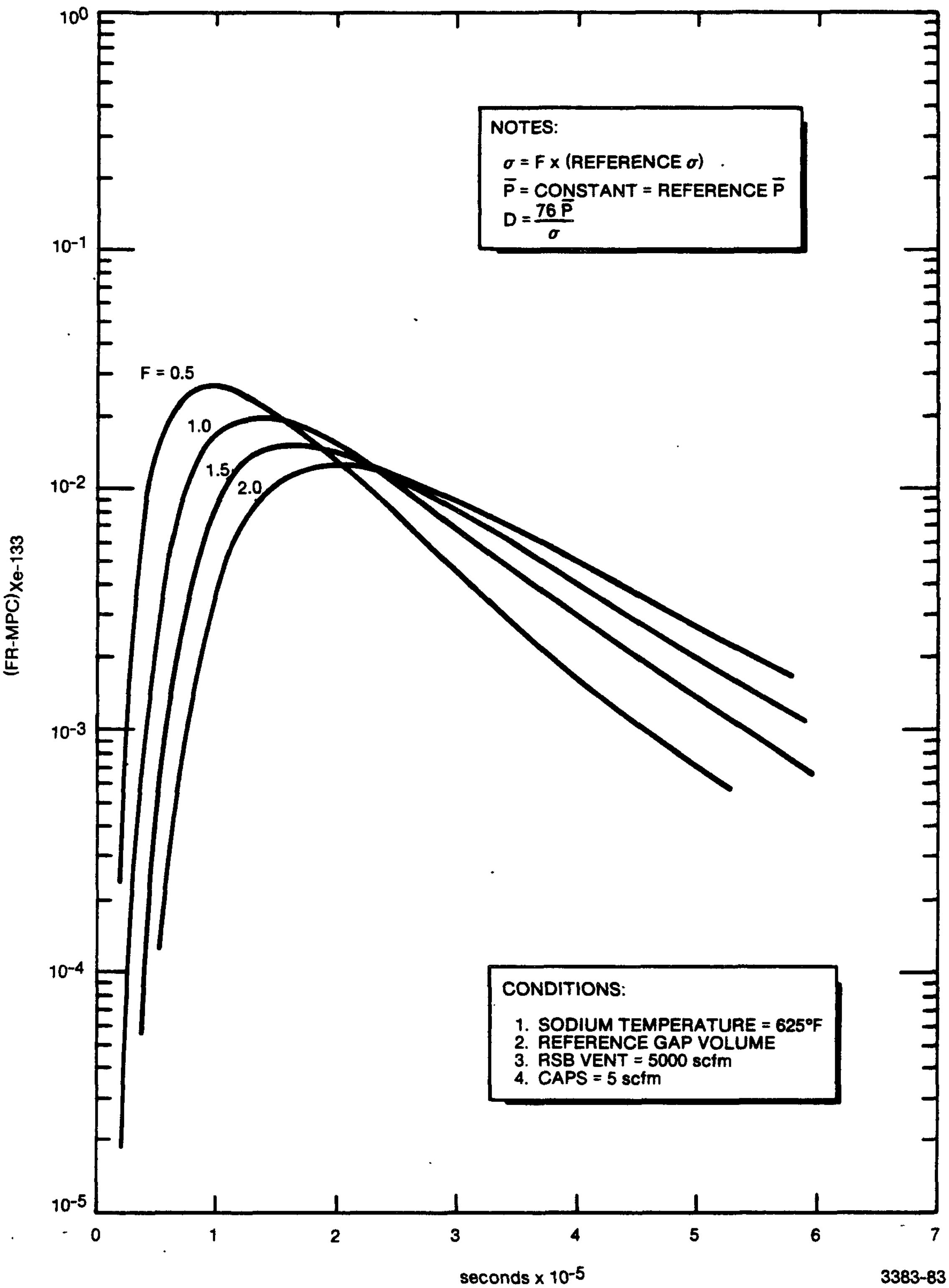

Figure 17. Parametric Study Utilizing EPR Equivalent Seal for EVST to Indicate Effect of Solubility on Xe-133 Leakage for Burst of an Entire Fuel Assembly

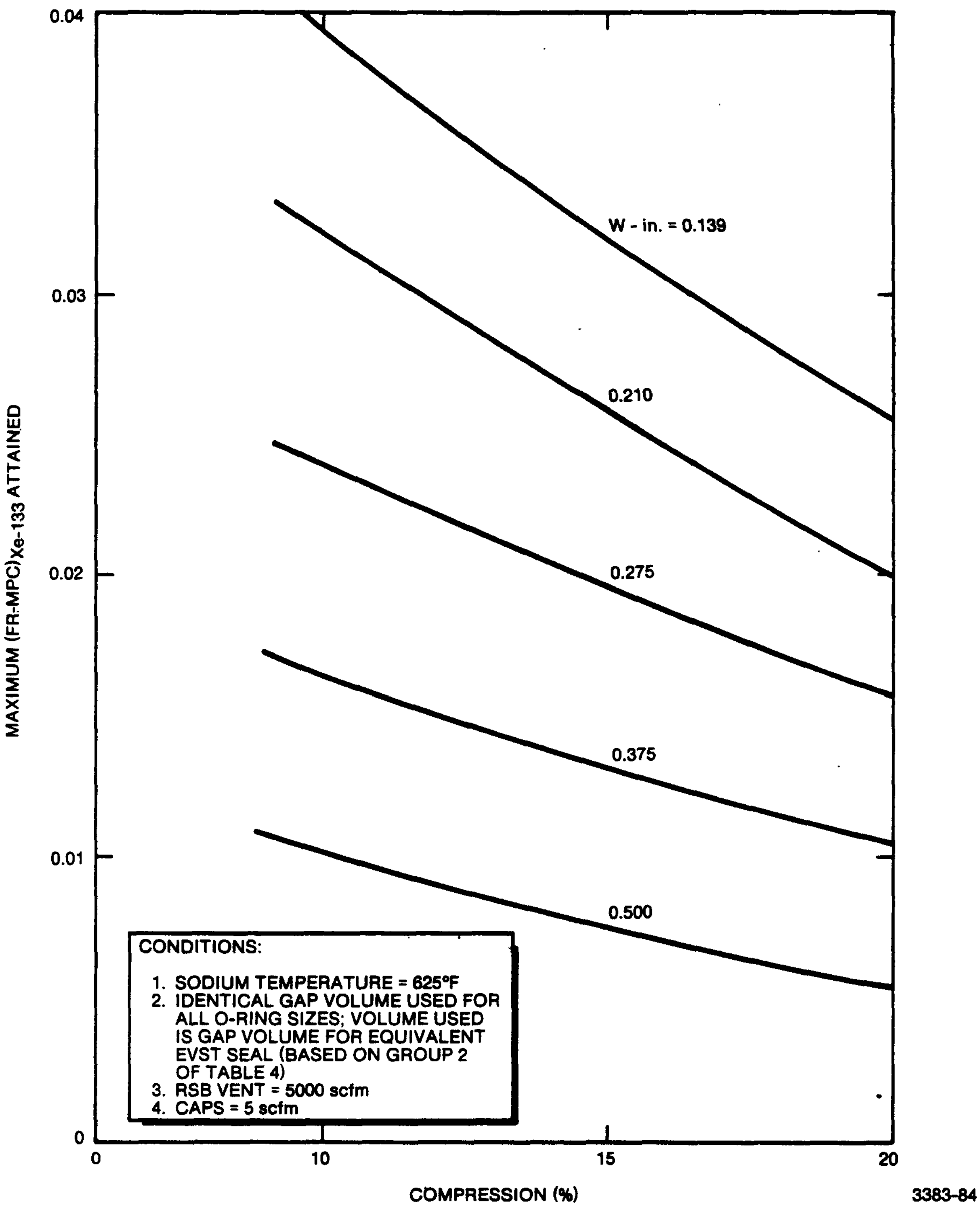

Figure 18. Parametric Study Utilizing EPR Equivalent Seal for EVST to Indicate Effect of O-Ring Percent Compression and Initial Cross-Sectional Diameter (W) on Maximum Attained Xe-133 Leakage for Burst of an Entire Fuel Assembly

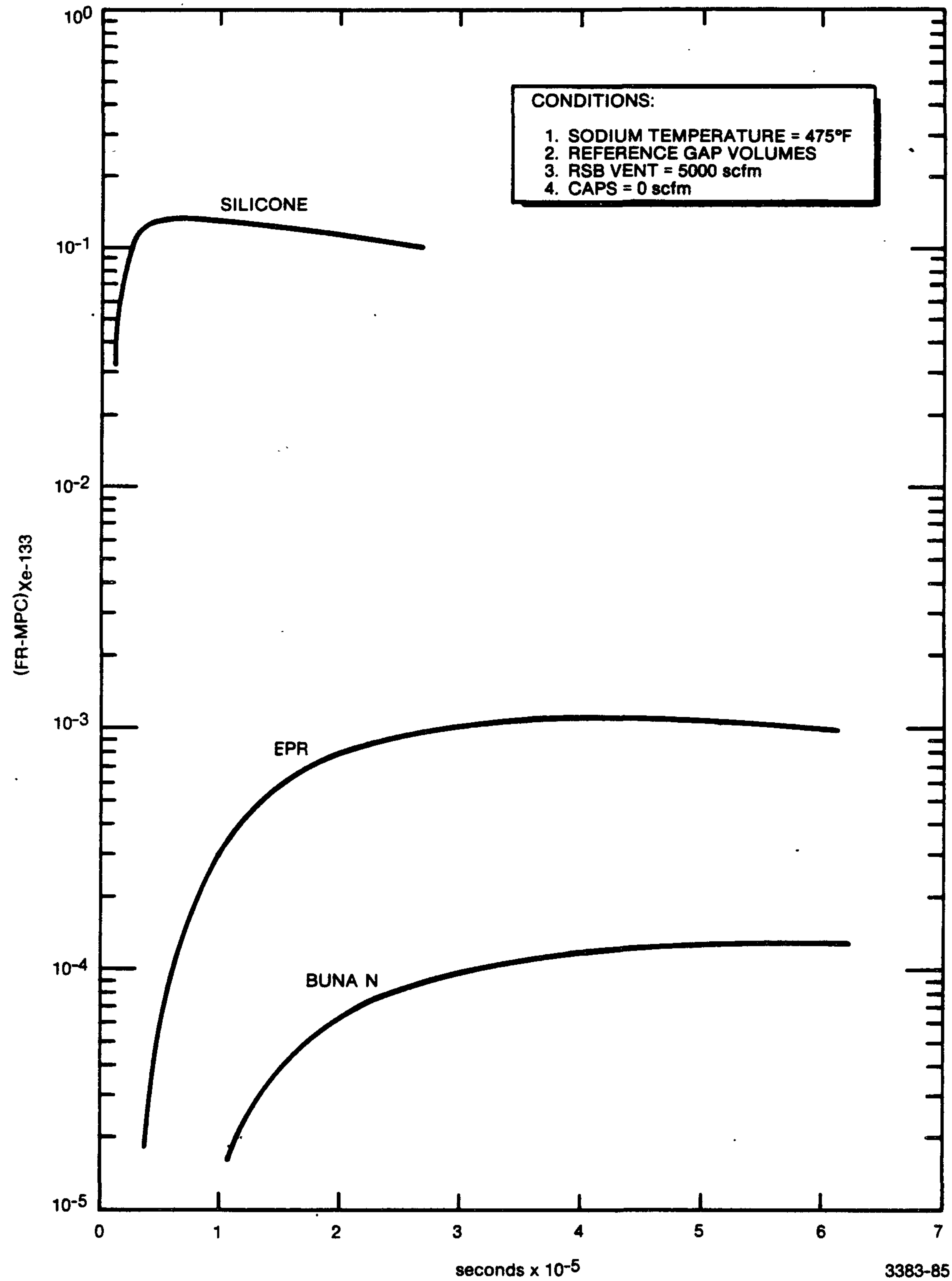

Figure 19. Effect of Elastomer Material on Xe-133 Leakage from EVST and Mated EVTM for Burst of Two Fuel Pins

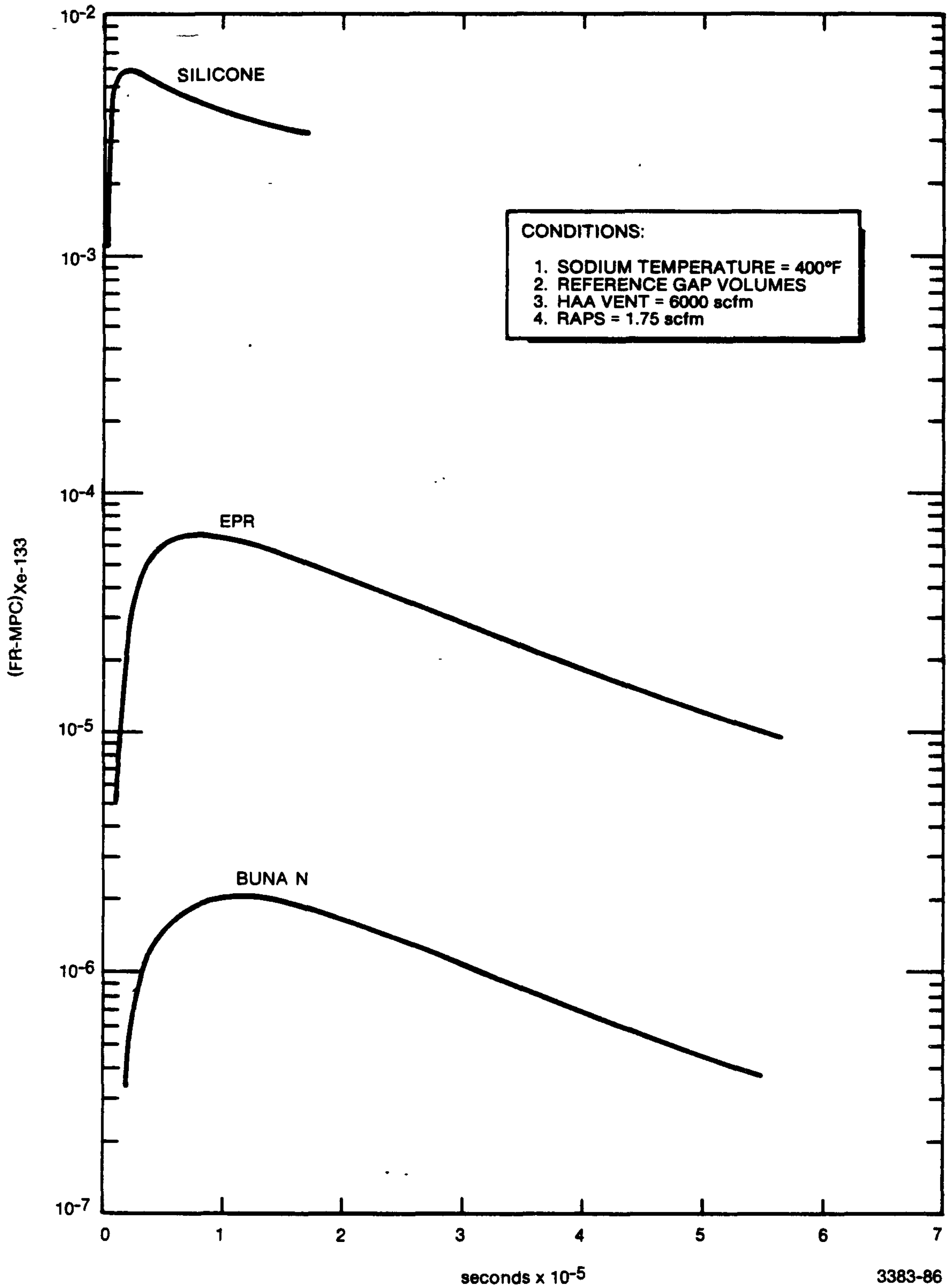

Figure 20. Effect of Elastomer Material on Xe-133 Leakage to HAA from IVTM When Mated to Reactor at 40 h After Reactor Shutdown and 1% Failed Fuel in Reactor at Shutdown

Figure 15 indicates that if the permeability data used within the study should be different, there would be a change in the maximum FR-MPC and in the time to reach peak concentrations. If the permeability factor were greater, peak leakage concentrations would be larger and reached faster. If the permeability factor were less, the peak concentrations would be lower and take longer to reach.

Figure 16 indicates essentially the same type of relationship for diffusion coefficient as Figure 15 does for permeability factor.

Figure 17 portrays essentially the same type of relationship for solubility constant as do Figures 15 and 16 except that it is inverted. As solubility goes up, the peak concentration goes down and shifts to longer times.

Figure 18 presents significant information in that it is different from most published data. It indicates that as cross-sectional diameter and initial compression are increased, peak FR-MPC is decreased.

Figure 19 involves the maximum normal operational radioactive case for the mated EVTM and EVST. It shows that all Buna N seals would have a peak FR-MPC that is significantly less than the maximum permissible leakage; EPR is just slightly greater, and silicone is significantly greater.

Figure 20 shows that the mated IVTM using all Buna N or EPR will easily meet the suggested leakage criteria. Silicone is slightly higher than the permissible leakage.

6.5 DISCUSSION OF PARAMETRIC LEAKAGE STUDY

The main conclusion of the parametric study was that the "leakage" requirements, as suggested, can be satisfied under normal conditions by proper selection of elastomeric materials. The report established, for the cases examined, that an all Buna N (nitrile) elastomer sealing system would always be below the suggested upper "leakage" rates. EPR sealing systems were either below or just slightly above these limits. An all-silicone sealing system was always significantly above the limits.

To appreciate fully the significance of these conclusions and their application to the selection of elastomeric materials for seals, several details of the calculations and other facts must be reviewed:

- The actual numerical results should be conservative as the values of the variables used to generate the FR-MPC were the most conservative available.
- The conclusions are based on the demonstrated fact that the radioisotope Xe-133 contributes the major portion of the FR-MPC buildup. All other radioactive isotopes are assumed to contribute negligible amounts of radioactivity and are, therefore, neglected.
- This study has been based on the radioactive buildup within the building and is not limited only to the actual quantity of leakage. Therefore, parameters such as RSB ventilation rate, CAPS rate, and RSB volume, as well as leakage rate, must be taken into consideration to determine whether the FR-MPC is too high. It has been demonstrated that if these values are changed, the time versus FR-MPC relationship would also be changed. Therefore, if in final design different values are used, new radioactivity buildup calculations may be necessary.
- The sealing network of subsystems contained within System 41 are those established within preliminary and conceptual designs. These seal networks may be slightly changed before final design is complete. Therefore, some new "leakage" calculations may be required to verify that the calculated values of FR-MPC are still acceptable within the test cases.
- Not all types of seal contribute equally to the radioactivity buildup. Ideally, metallic seals should leak/permeate very little. This is the case examined within the study. In reality, this is achievable, but it is quite likely that achieved tolerances would permit greater-than-anticipated leakage. Therefore, metallic seals are not recommended unless absolutely necessary for exceptionally high-temperature applications, too high for elastomers, or cases where longer service life is necessary.

  Solid-cross-section seals, such as O-rings, can essentially obtain ideal sealability and permit negligible "mechanical leakage, permitting only permeability." Therefore, their use is very desirable.

Inflatable seals have problems. The parametric study, under the idealistic condition of no mechanical leakage, indicated that in one case, a double set of inflatable seals could contribute as much as 30% leakage of the entire sealing network. Unfortunately, inflatable seals are essential to the designs of System 41 and must be used. Whenever possible, inflatable seals should have a solid-cross-section backup seal.

The result of the very high FR-MPC contribution from a few inflatable seals indicates that the leak rates of solid-cross-section seals are more conservative than estimated. This should permit further leeway in the selection of higher permeability elastomers for some solid-cross-section seals; the increased leakage should be minimal.

- Only a few limited cases have been evaluated within the parametric study. These cases indicate the limits and trends of three basic elastomer materials. The cases are quite satisfactory for indicating acceptable material selection, but additional studies may be required to certify the acceptability of material selection for final design.

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7.0 BASIS FOR ELASTOMER SELECTION

Each of the elastomer types chosen for final consideration has certain properties useful for seal applications, based on its structure and composition. Table 10 briefly compares properties of the three elastomers of interest.

TABLE 10

PROPERTIES OF THREE ELASTOMERS

Elastomer	Positive	Negative
Buna N	Lowest permeability Low compression set Radiation resistance to ~10^8R+ Mechanical properties	Intermediate thermal properties (temperature life)
EPDM	Thermal properties (temperature life) Radiation resistance to ~10^8R+ Low compression set Mechanical properties	Intermediate permeability
Silicone	Thermal properties (temperature life) Radiation resistance to ~10^8R	High permeability Mechanical properties

As is evident, seal selection and optimization require a compromise and consideration of specific applications in various System 41 subsystems. For example, in applications involving high temperature (in the range of 350 to 500°F, for example) and where use of an elastomeric seal is dictated, a silicone elastomer may be required in spite of its negative characteristics. Such use may require acceptance of higher leakage levels, more frequent replacement, etc.

With the above concept in mind, System 41 seal applications were reviewed with cognizant engineers and designers, and the various operating parameters were tabulated for study and seal optimization. Such study has indicated that the great majority of the "normal" and "upset" conditions of seal temperature, radiation, and operation (seal type, static, dynamic, etc.) would be better handled by Buna N (nitrile) rubber, this type giving the lowest possible leakage by gas permeability. Intermediate temperature range applications, presumably above Buna N capabilities, will be handled by EPDM, leaving a few to silicone rubber seals, possibly metal rings, or other construction.

Summarizing, the following general criteria were used to select materials:

- Lowest permeability to reactor cover gases commensurate with the temperature requirements of the majority of applications
- Gamma radiation resistance of the three elastomer types about equivalent at approximately 10^8 rads
- Temperature limits for 5-year life (based on test data and extrapolations; nominal compressions to 30% maximum)

Buna N	~140°F
EPDM	~210°F
Silicone	~220°F.

Detailed seal selections and recommendations are presented in the appendix. For clarity, the basis for the selections are restated as follows:

- Five-year seal life under normal conditions with maximum sealing properties
- Under some conditions, 5-year life may not be obtainable, due to the variety of possible transients, too complex for analysis
- After "upset" (or accident) conditions, though corrected as soon as practical, the effects of such conditions (excess temperature, radiation exposure, etc.) should be considered as to their effects on seals and the desirability of seal replacement
- Seals exposed to cycling temperature are subject to life variations dependent on extent of temperature excursions, number of cycles in lifetime, amount of prestress on seal, etc.

- In consideration of seal materials, AI Engineering has reviewed but is not confirming seal design or mechanical arrangement. Materials selection to accommodate proposed designs have been made. These are given in the appendix.

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APPENDIX

SEAL DATA CHARTS WITH ELASTOMER SELECTIONS

SYSTEM: 41 SUBSYSTEM: IVTM COMPONENT:

Seal No.	Seal Name	Seal Format: Type	Seal Format: Applications	Temperature: (1) Accident (°F)	Time	Norm (°F)(2)	Time	No. Cycles	Atmosphere: Media	P(Psig)	Radiation Dose Rate /Ref: Accident (rad/h)	Normal (rad)	Nominal Dia (ID) (in.)	Cross Section Dia. (in)	Gland Width	Dimension (in.) Depth (in.)	Nominal Comp. (%)	Seal Length (in.)	Gland Surface Finish (rms): Top	Bot	Side	Leakage Path	Material	Vendor & Compound	Part No.	Hardness Shore A	Normal Maintenance Period (years)	Desirable Service Life (years)	Comments or Special Problems
1a 1b 1c	Grapple Finger Actuator Rod	T-Ring	Dyn.	NA		100	Contin's		Argon	5	NA	Nil	1.187		0.185	0.110		3.729	32	32	32	—0—0—0—	Buna N	Parker N741		75	5	5	
2a 2b	Grapple Finger Actuation Rod Seal Housing	O-Ring	Static	NA		100	Contin's		Argon	5	NA	Nil	1.625	0.139	0.199	0.111	20	5.105	32	32	32	—0—0—	Buna N	Parker N741		75	5	5	
3a 3b 3c	Stem Assy - Grapple	T-Ring	Dyn.	350	~2 min	300	~2 min	2088/REF	Argon	5	NA	Nil	3.250		0.281	0.177		10.21	32	32	32	—0—0—0—	EPR	Parker E692		75	5	5	
4a 4b	Stem Seal and Bushing Housing	O-Ring	Static	NA		~200	Contin's		Argon	5	NA	Nil	4.375	0.139	0.159	0.111	20	13.744	32	32	32	—0—0—	EPR	Parker E692		75	5	5	
5a 5b 5c	Holddown Sleeve Drive Shaft A	T-Ring	Dyn.	NA		300	~2 min	2088/REF	Argon	5	NA	Nil	1.500		0.188	0.112		4.712	32	32	32	—0—0—0—	EPR	Parker E692		75	5	5	
6a 6b	Holddown Sleeve DriveShaft Seal Housing A	O-Ring	Static	NA		200	Contin's		Argon	5	NA	Nil	2.500	0.139	0.159	0.111	20	7.854	32	32	32	—0—0—	EPR	Parker E692		75	5	5	
7a 7b 7c	Holddown Sleeve Drive Shaft B	T-Ring	Dyn.	NA		300	~2 min	2088/REF	Argon	5	NA	Nil	1.500		0.138	0.112		4.712	32	32	32	—0—0—0—	EPR	Parker E692		75	5	5	
8a 8b	Holddown SleeveDriveShaft Seal Housing B	O-Ring	Static	NA		200	Contin's		Argon	5	NA	Nil	2.500	0.139	0.159	0.111	20	7.854	32	32	32	—0—0—	EPR	Parker E692		75	5	5	
9a 9b 9c	Holddown Sleeve Drive Shaft C	T-Ring	Dyn.	NA		300	~2 min	2088/REF	Argon	5	NA	Nil	1.500		0.138	0.112		4.712	32	32	32	—0—0—0—	EPR	Parker E692		75	5	5	
10a 10b	Holddown SleeveDriveShaft Seal Housing C	O-Ring	Static	NA		200	Contin's		Argon	5	NA	Nil	2.500	0.139	0.159	0.111	20	7.854	32	32	32	—0—0—	EPR	Parker E692		75	5	5	
11a 11b	Identifier Pawl Shaft	O-Ring	Dyn.	NA		200	Contin's		Argon	5	NA	Nil	1.000	0.139	0.159	0.111	20	3.142	32	32	32	—0—0—	EPR	Parker E692		75	5	5	
12a 12b	Identifier Pawl Shaft Seal Housing	O-Ring	Static	NA		200	Contin's		Argon	5	NA	Nil	2.500	0.139	0.159	0.111	20	7.854	32	32	32	—0—0—	EPR	Parker E692		75	5	5	
13a 13b 13c	IVTM Port Seals	O-Ring	Static	NA		200	Contin's		Argon	5	NA	Nil	18.000	0.275	0.310	0.221	20	56.549	32	32	32	—0—0—0—	EPR	Parker E692		75	5	5	

SYSTEM: 41 SUBSYSTEM: IVTM COMPONENT: Port Adapter

Seal No.	Seal Name	Seal Format: Type	Seal Format: Applications	Temperature: Accident (°F)	Time	Norm* (°F)	Time	No. Cycles	Atmosphere: Media	P(Psig)	Radiation Dose Rate: Accident (rad)	Normal (rad)	Nominal Dia. (in.)	Cross Section Dia. (in)	Gland Width (in.)	Dimension Depth (in.)	Nominal Comp. (%)	Seal Length (in.)	Gland Surface Finish (rms): Top	Bot	Side	Leakage Path	Material	Vendor & Compound	Part No.	Hardness Shore A	Normal Maintenance Period (years)	Desirable Service Life (years)	Comments or Special Problems
1a 1b	Upper Sleeve	O-Ring	Static	NA	–	120°F	2 day/yr Duration	–	Argon	5	NA	Nil	19	0.139	0.159	0.111	20	59.69	32	32	63	o-o ② ①	Buna N	Parker N741	–	75	5	5	"O" rings must be made per order
2a 2b	Lower Sleeve	↓	↓	↓	–	120°F	↓	–	↓	↓	↓	↓	19	0.139	0.159	0.111	↓	59.69				o-o	Buna N	↓	–	↓	↓	↓	"O" rings must be made per order
3a 3b	Guide-Roller Mounting Shaft				–	120°F		–					3.75	0.139	0.159	0.111		11.78				o ③ o	Buna N		–				
4a 4b	Guide-Roller Mounting Shaft				–	120°F		–					3.75	0.139	0.159	0.111		11.78				o ③ o	Buna N		–				
5a 5b	Shaft-Roller Mounting				–	120°F		–					2.75	0.139	0.159	0.111		8.64				o ③ o	Buna N		–				
6a 6b	Shaft-Roller Mounting				–	120°F		–					2.75	0.139	0.159	0.111		8.64				o ③ o	Buna N		–				
7	IVTM Port Mounting Face				–	200°F		–					22.38	0.210	Dove Tail 0.173	0.168		70.31				② ③	EPR		–				
8	IVTM Port Mounting Face				–	200°F		–					24.38	0.210	Dove Tail 0.173	0.168		76.59				o ③ ②	EPR		–				
9	AHM Floor Valve Mating Surface				–	120°F		–					25.62	0.275	0.310	0.220		80.49				③ o	Buna N		–				"O" rings must be made per order
10	AHM Floor Valve Mating Surface	↓	↓	↓	–	120°F	↓	–	↓	↓	↓	↓	29.38	0.275	0.310	0.220	↓	92.30				o ③	Buna N	↓	–	↓	↓	↓	"O" rings must be made per order
11a 11b	Inner Seal	O-Ring	Static	NA	–	120°F	2 day/yr Duration	–	Argon	5	NA	Nil	21.00	0.275	0.310	0.220	20	65.97	32	32	63	o ② o ③	Buna N	Parker N741	–	75	5	5	
																													(1) Seals only in use when sleeve in place
																													(2) Sleeve in place leakage path
	*Normally at Ambient Temperature																												(3) Sleeve not in place leakage path

SYSTEM: 41 SUBSYSTEM: IVTM COMPONENT: Storage Adaptor

A4

Seal No.	Seal Name	Seal Format: Type	Seal Format: Applications	Temperature: Accident (°F)	Temperature: Time	Temperature: Norm (°F)	Temperature: Time	Temperature: No. Cycles	Atmosphere: Media	Atmosphere: P(Psig)	Radiation Dose Rate: Accident (rad)	Radiation Dose Rate: Normal (rad)	Nominal Dia. (in.)	Cross Section Dia. (in.)	Gland Dimension: Width (in.)	Gland Dimension: Depth (in.)	Nominal Comp. (%)	Seal Length (in.)	Gland Surface Finish (rms): Top	Bot	Side	Leakage Path	Material	Vendor & Compound	Part No.	Hardness Shore A	Normal Maintenance Period (years)	Desirable Service Life (years)	Comments or Special Problems
1a 1b	Upper Sleeve	"O" Ring	Static	NA	–	≤120°F	Duration	–	Argon	5	NA	Nil	19	0.139	0.159	0.111	20	59.69	32	32	63	① ②	Buna N	Parker N741	–	75	5	5	Special "O" Ring
2a 2b	Lower Sleeve												19	0.139	0.169	0.111		59.69				① ②							Special "O" Ring
3a 3b	Guide-Roller Mounting Shaft												3.75	0.139	0.159	0.111		11.78				②							
4a 4b	Guide-Roller Mounting Shaft												3.75	0.139	0.159	0.111		11.78				②							
5a 5b	Shaft-Roller Mounting												2.75	0.139	0.159	0.111		8.64				②							
6a 6b	Shaft-Roller Mounting												2.75	0.139	0.159	0.111		8.64				②							
7	Lower Face												22.38	0 210	Dove Tail 0.173	0.168		70.31				③							
8	Lower Face												24.38	0.210	Dove Tail 0.173	0.166		76.59				③							
9	AHM Floor Valve Mating Surface												25.62	0.275	0.310	0.220		80.49				②							Special "O" Ring
10	AHM Floor Valve												29.38	0.275	0.310	0.220		92.30				③							Special "O" Ring
11a 11b	Inner Seal	"O" Ring	Static	NA	–	≤120°F	Duration	–	Argon	5	NA	Nil	21.00	0.275	0.310	65.97	20	65.97	32	32	63	② ③	Buna N	Parker N741	–	75	5	5	

① Seal used only when Sleeve in place

② Sleave in place leakage path

③ Sleeve not in place leakage path

SYSTEM: 41 SUBSYSTEM: 41-6 COMPONENT: CASIC-FHC SEAL ASSY (CONCEPTUAL DESIGN)

A5

Seal No.	Seal Name	Seal Format: Type	Seal Format: Applications	Temperature: Accident (°F)	Temperature: Time	Temperature: Norm (°F)	Temperature: Time h/yrs	Temperature: No. Cycles	Atmosphere: Media	Atmosphere: P(Psig)	Radiation Dose Rate: Accident (rad)	Radiation Dose Rate: Normal (rad)	Nominal Dia. (in.)	Cross Section Dia. (in.)	Gland Dimension: Width (in.)	Gland Dimension: Depth (in.)	Nominal Comp. (%)	Seal Length (in.)	Gland Surface Finish (rms): Top	Bot	Side	Leakage Path	Material	Vendor & Compound	Part No.	Hardness Shore A	Normal Maintenance Period (years)	Desirable Service Life (years)	Comments or Special Problems
1 a b	Support Fitting To FHC Port	0 0	S S	Less Than Normal Cases	for All	~150 ~130	918	68/yr	Argon & Dowthery Vapors	20.0 0.15	144 mrad hr	5 mRem hr	~18.80 ~20.36										Buna N	Parker N741	–	75	Once a year	5 yr 5 yr	
2 a b	Stem Bellows To Support Fitting	0 0	S S			~200 ~180							~17.76 ~19.28										EPR	Parker E692	–	75	Once a year	5 yr 5 yr	
3	Stem Case Upper To Stem Case Lower	0	S			~150							~19.80										Buna N	Parker N741	–	75	Once a year	5 yr	
4	Stem Liner Lower To Stem Case Upper	0	S& D			~200							~19.00										EPR	Parker E692	–	75	Once a year	5 yr	
5	Stem Liner Lower To Stem Flange	0	S			~210							~16 84										EPR	Parker E692	–	75	Once a year	5 yr	
6a b	Adapter Bellows To Adapter Flange	0	S S			~210 ~200							~14.72 15 84										EPR	Parker E692	–	75	Once a year	5 yr	
7	Adapter Case To SFSC Upper	0	S			~400							~10.32										Buna	Parker N741	–	75	Once a year	5 yr	
8	Plug Cover To Adapter Case	0	S			~150							~9.0										Buna	Parker N741	–	75	Once a year	5 yr	
9	Plug Cover To Plug	0	S			~150							~8.63										Metal		–		Once a year	5 yr	
10	Plug Cover To Plug	0	S			~420							~9.60										Buna N	Parker N741	–	75	Once a year	5 yr	
11	Stem Case Lower To Adjustment Tube	0	S& D			~140							~19.28										Buna N	Parker N741	–	75	Once a year	5 yr	
12	Adjustment Tube To Stem Bellows Lower	0	S			~120							~20.48										Buna N	Parker N741	–	75	Once a year	5 yr	
13	Stem Flange Bolt Seal	0	S			~120							~0 75										Buna N	Parker N741	–	75	Once a year	5 yr	
14	Stem Bellows Lower To Stem Liner Lower	0	S			~140							~17.28																

SYSTEM: 41 SUBSYSTEM: EVTM COMPONENT: FLOOR VALVE

A 6

Seal No.	Seal Name	Seal Format: Type	Seal Format: Applications	Temperature: (1) Accident (°F)	Time	Norm (°F)	Time	No. Cycles	Atmosphere: Media	P(Psig)	Radiation Dose Rate: Accident rad/hr	Normal (rad)	Nominal Dia. (in.)	Cross Section Dia. (in)	Gland Width	Dimension (in.)	Depth (in.)	Nominal Comp. (%)	Seal Length (in.)	Gland Surface Finish (rms): Top	Bot.	Side	Leakage Path	Material	Vendor & Compound	Part No.	Hardness Shore A	Normal Maintenance Period (years)	Desirable Service Life (years)	Comments or Special Problems
1 2	32 & 33	0 0	S S	269					Ar Ar	± 15	1 x 10^5	1 x 10^6 5yr life	~18.3 ~16.1	0.5 0.5			57.5 50.6		57.5 50.6					EPR	Parker E692	–	75	5	5	
3 4	34 (upper) 35	Inflatable Inflatable	S S	(4)					Ar Ar	± 15	1 x 10^6	4 x 10^7 5 yrlife	15.00	NA			~94.5 ~79.0		94.5 79.0							–				
5 6	19 20	0 0	S S	195					Ar Ar	± 15	Nil	Nil	~66.2 ~64.0	0.375 0.375			200.3 194.0		200.3 194.0					Buna N	Parker N741	–	75			
7 8	54 55	0 0	S S	195					Ar Ar	± 15	Nil	Nil	~58.0 ~60.5	0.375 0.375			183.0 189.5		183.0 189.5					Buna N	Parker N741	–	75			
9 10	34 (lower) 35	Inflatable Inflatable	S S	(4)					Ar Ar	± 15	1 x 10^6	4 x 10^7 5 yrlife	15.00 12.50	NA			~47.2 ~42.5		47.2 42.5							–				
	5 6	0 0	D S	146					Ar Ar	± 15	Nil	Nil	1.609 4.234	0.139 0.139			~5.1 ~13.4		5.1 13.4					Buna N	Parker N741	–	75	5	5	
13	50 (not a seal)	NA	–	600					Ar	± 15	1 x 10^6	4 x 10^7 5 yrlife	11.50	NA			36.2		36.2				NA			–		5	5	

Radiation (5 year life) Dose = 1 min/pass x 120 fuel assembly/year x 5 year x 4 pass/assembly = 40 hr exposure in 5 year

NA - Not Applicable

(4) Bulk of seal at 269 F
Bead of seal at 487 F
~~(Inflated condition)~~

(1) Assume stuck fuel assembly adjasent to seal.

SYSTEM: 41 SUBSYSTEM: AHM COMPONENT: FLOOR VALVE

A 7

Seal No.	Seal Name	Seal Format: Type	Seal Format: Applications	Temperature: (2) Accident (°F)	Time	Norm (°F)(2)	Time	No. Cycles	Atmosphere: Media	P(Psig)	Radiation (2) Dose: Accident (rad/h)	Normal (rad)	Nominal Dia. (ID) (in.)	Cross Section Dia. (in)	Gland Width	Dimension (in.)	Depth (in.)	Nominal Comp. (%)	Seal Length (in.)	Gland Surface Finish (rms): Top	Bot.	Side	Leakage Path	Material	Vendor & Compound	Part No.	Hardness Shore A	Normal Maintenance Period (years)	Desirable Service Life (years)	Comments or Special Problems
1 2	38 39	0 0	S S	(1)					Ar	±15	≤6000	6000*	~26.8 ~29.0	0.5 0.5			–	–	84.5 91.0	–	–	–		EPR	Parker E692	–	75	5	5	
3 4	36 (upper) 37	Inflatable Inflatable	S S	(1)					Ar	±15	≤6000	6000*	25.75 23.25	NA			–	–	~82.0 ~76.5	–	–	–				–		5	5	
5 6	19 20	0 0	S S	(1)					Ar	±15	Nil	6000*	~64.0 ~62.0	0.375 0.375					200.3 194.0					Buna N	Parker N741	–	75	5	5	
7 8	54 55	0 0	S S	(1)					Ar	±15	Nil	6000*	~58.0 ~60.5	0.375 0.375			–	–	183.0 189.5	–	–	–		Buna N	Parker N741	–	75	5	5	
9 10	36 (lower) 37	Inflatable Inflatable	S S	(1)					Ar	±15	≤6000	6000*	25.75 23.25	NA			–	–	~82.0 ~76.5	–	–	–						5	5	
11a-b 12a-b	5 6	0 0	D S	(1)					Ar	±15	≤6000	6000*	1.609 4.234	0.139 0.139			–	–	~5.1 ~13.4	–	–	–		Buna N	Parker N741	–	75	5	5	
13	49 (not a seal)	NA	-	(1)					Ar	±15	≤6000	6000*	22.13	NA			–	–	~63.2	–	–	–	NA			–		5	5	

Total radiation dose (5 year) = 20 DRCL/yr. x 5 yr. x 10 min/tran. x $\frac{1 \text{ hr}}{60 \text{ min}}$ x 6000 rad dose (5 year)

(1) Accident Condition expected to be less than 400°F.

(2) Accident Condition - Assumes ajacent stuck fuel assemble

(3) Selection based upon EVTM floor valve.

1. Accident Condition expected to be less than 400°F.
2. Accident Condition- ~~Assumes Ajacent Stuck Fuel~~ Assemble.
3. Selection Based upon EVTM Floor Valve.

SYSTEM: 41 SUBSYSTEM: EVTM COMPONENT: Grapple Drive Housing (Conceptual drawing used, changes have been made in preliminary design)

Seal No.	Seal Name	Seal Format: Type	Seal Format: Applications	Temperature: Accident (°F)	Time	Norm (°F)	Time	No. Cycles	Atmosphere: Media	P(Psig)	Radiation Dose Rate: Accident (rad/h)	Normal (rad/h)	Nominal Dia. (in.)	Cross Section Dia. (in)	Gland Width	Dimension (in.)	Depth (in.)	Nominal Comp. (%)	Seal Length (in.)	Gland Surface Finish (rms): Top	Bot.	Side	Leakage Path	Material	Vendor & Compound	Part No.	Hardness Shore A	Normal Maintenance Period (years)	Desirable Service Life (years)	Comments or Special Problems
1 2	Chainfall Cavity to Grapple Drive Housing	0	S S	250		150			Ar	±15	NA	50	~31 ~31	.25									—o—o—	BunaN	Parker N741	-	75	5 5	5 5	
3 4	Grapple Drive Top to Grapple Drive Sides		S S										~87.5x28 ~87.5x28										—o—o—	BunaN		-		5 5	5 5	Rectangular Path
5 6	Side to Top		S S										~84x28 ~84x28										—o—o—	BunaN		-		5 5	5 5	Rectangular Path
7 8	Chain Wheel Cover to Top		S		(Note: Thermal Study not Performed at this time)								~35 ~35										—o—o—	BunaN		-		5 5	5 5	
9 10	Encoder Sleeve		S S										~ 8 ~ 8										—o—o—	BunaN		-		5 5	5 5	
11 12	Encoder Shaft		D D										~ 1.75 ~ 1.75										—o—o—	BunaN		-		5 5	5 5	
13 14	Motor Drive Sleeve		S S										~ 8 ~ 8										—o—o—	BunaN		-		5 5	5 5	
15 16	Motor Drive Shaft		D D										~ 1.75 ~ 1.75										—o—o—	BunaN		-		5 5	5 5	
17 18	Actuator Sleeve		S S										~ 8 ~ 8										—o—o—	BunaN		-		5 5	5 5	
19 20	Actuator Shaft		D D										~ 1.75 ~ 1.75										—o—o—	BunaN		·		5 5	5 5	
21a-f 22a-f	Glove Parts (6)		S S										~11 ~11										—o—o—	BunaN		-		5 5	5 5	Exact size and locationo
23a-f 24a-f	Windows (6)		S S										~11 ~11										—o—o—	BunaN		-		5 5	5 5	unknown presently
25 26	Chain Fall Cavity (bottom)	0	S S	250		150			Ar	±15	NA	50	~12x36 ~12x36	.25									—o—o—	BunaN	Parker N714	-	75	5 5	5 5	Rectangular Path Demensions from J. Belluomini

SYSTEM: 41 SUBSYSTEM: EVTM COMPONENT: VIEW PORT

Seal No.	Seal Name	Seal Format: Type	Seal Format: Applications	Temperature: Accident (°F)	Time	Norm (°F)	Time	No. Cycles	Atmosphere: Media	P(Psig)	Radiation Dose Rate: Accident (rad)	Normal (rad)	Nominal Dia. (in.)	Cross Section Dia. (in)	Gland Width	Dimension (in.)	Depth (in.)	Nominal Comp. (%)	Seal Length (in.)	Gland Surface Finish (rms): Top	Bot.	Side	Leakage Path	Material	Vendor & Compound	Part No.	Hardness Shore A	Normal Maintenance Period (years)	Desirable Service Life (years)	Comments or Special Problems
1 2	Outside Sleeve Flange	0 0	S S	300		170		Ar Ar	15 15	3×10^2	N11	13.25 12.00	0.25 0.25										—o—o→	EPDM	Parker E692	2-279 2-278	75	5 5	5 5	
3 4	Camera Housing	0 0	S S	300		170		Ar Ar	15 15	3×10^2	N11	11.5 11.5	0.25 0.25										—o—o→	EPDM	Parker E692	2-452 2-278	75	5 5	5 5	
5 6	Camera Sleave Glass Filter	0 0	S S	310		170		Ar Ar	15 15	3×10^2	N11	8.75 8.75	0.25 0.25										—o—o→	EPDM	Parker E692	2-269 2-269	75	5 5	5 5	
7 a-d	Inside Fitting Seal Glas Filter	0	S	300-323		170		Ar	15	3×10^3	N11	0 5	0.125										—o—o→	EPDM	Parker E692	—	75	5 5	5 5	
8 a-d	Outside Fitting	0	S	300-323		170		Ar	15	3×10^3	N11	1.0	0.125										o—o—o→	EPDM	Parker E692	2-210	75	5	5	4 glass rods with identical seals on all
9 a-d	Glass Fiber Seal	0	S	300-323		170		Ar	15	3×10^3	N11	0 5	0.125										—o—o→	EPDM	Parker E692	—	75	5	5	
10 a-d	Vibration Supresson	0	S	350-408		170		Ar	15	3×10^4	10	1.0	0.25										—o—o→	EPDM	Parker E692	2-204	75	5 5	5 5	Not for sealing
16 17	View Port to Coldwall	0 0	S S	500-530		170		Ar Ar	15 15	1×10^6		30.0 30.0	0.25 0.25										—o—o→	EPDM	Parker E692	—	75	5 5	5 5	

*No thermal analysis - rough estimate

SYSTEM: 41 SUBSYSTEM: EVTM COMPONENT: Drip Pan

A10

Seal No.	Seal Name	Seal Format: Type	Seal Format: Applications	Temperature: Accident (°F)	Time	Norm (°F)	Time	No. Cycles	Atmosphere: Media	P(Psig)	Radiation Dose Rate: Accident (rad/h)	Normal (rad/h)	Nominal Dia. (in.)	Cross Section Dia. (in)	Gland Width	Gland Dimension (in.)	Depth (in.)	Nominal Comp. (%)	Seal Length (in.)	Gland Surface Finish (rms): Top	Bot.	Side	Leakage Path	Material	Vendor & Compound	Part No.	Hardness Shore A	Normal Maintenance Period (years)	Desirable Service Life (years)	Comments or Special Problems
1	Drip Pan	0	S	180		130			Ar	±15	200	1	67.75	.25	.305		.201			32	32	32	-o—o-	BunaN	Parker N741	–	75	5	5	
2	to View Port	0	S										65.50	.25			.201			32	32	32						5	5	
10	Drip Pan to	Quad	D	200		100			Ar	±15	Nil	Nil	1.875	.125	.155		.11[illegible]			16	16	16	-o—o-	BunaN	Parker N741	–	75	5	5	
11	Drive Shaft	Quad	D										1.875	.125						16	16	16						5	5	
12	Drive Shaft	0	S	200		100			Ar	±15	Nil	Nil	5.25	.25	.310		.201			32	[illegible]	[illegible]	[illegible]	BunaN	Parker N741	–	75	5	5	
13	Housing	0	S										5.25	.25	.310		.201			32	32	32						[illegible]	5	

SYSTEM: 41 SUBSYSTEM: EVTM COMPONENT: EXTENDER

A11

Seal No.	Seal Name	Seal Format: Type	Seal Format: Applications	Temperature: Accident (°F)	Time	Norm (°F)	Time	No. Cycles	Atmosphere: Media	P(Psig)	Radiation Dose Rate: Accident (rad)	Normal (rad)	Nominal Dia. (in.)	Cross Section Dia. (in)	Gland Width	Gland Dimension (in.)	Depth (in.)	Nominal Comp. (%)	Seal Length (in.)	Gland Surface Finish (rms): Top	Bot.	Side	Leakage Path	Material	Vendor & Compound	Part No.	Hardness Shore A	Normal Maintenance Period (years)	Desirable Service Life (years)	Comments or Special Problems
1 2	Extender to Drip Pan	0 0	S S	350		100			Ar	15	200	Nil	~ 67	0.25	0.308		0.205	20-30		32	32	32	-o-o-	Buna N	Parker N741	–	75	5	5	
3 4	Bellows to Extender	0 0	S S	750		100			Ar	15	1.5 x 10^5	600	~ 23.75	0.25	0.308		0.205	20-30		32	32	32	-o-o-	Buna N	Parker N741	–	75	5	5	
5	Checkline Seal	0	S	500		<200			Ar	15	1.5 x 10^5	600	~ 1.25	0.25	0.308		0.205	20-30		32	32	32				–		5	5	
6 7	Bellow to Bottom Flange	0 0	S	890		220			Ar	15	[illegible] x 10^6	400	~ 14	0.25	0.290		0.205	20-30		32	32	32	-o-o-→	EPR	Parker E692	–	75	5	5	

* Maximum Radiation close as fuel element passes seal. Identical to that of stuck fuel assembly which is adjacent.

SYSTEM: 41 SUBSYSTEM: EVTM COMPONENT: Coldwall

A12

Seal No.	Seal Name	Seal Format: Type	Seal Format: Applications	Temperature: Accident (°F)	Time	Norm (°F)	Time	No. Cycles	Atmosphere: Media	P(Psig)	Radiation Dose Rate: Transient (rad/h)	Normal (rad/h)	Nominal Dia. (in.)	Cross Section Dia. (in)	Gland Width	Dimension (in.)	Depth (in.)	Nominal Comp. (%)	Seal Length (in.)	Gland Surface Finish (rms): Top	Bot.	Side	Leakage Path	Material	Vendor & Compound	Part No.	Hardness Shore A	Normal Maintenance Period (years)	Desirable Service Life (years)	Comments or Special Problems
1 2	Coldwall to Grapple Drive System	0 0	S S	250		200			Ar Ar	±15 ±15	Not Applicable	50	10.5 11.5	.25 .25	Special See Drawing								—o—o—	EPR	Parker E692	2-274 2-276	75	5 5	5 5	Special Dove Tail Gland.

SYSTEM: 41 SUBSYSTEM: EVTM COMPONENT: Closure Valve

A13

Seal No.	Seal Name	Seal Format: Type	Seal Format: Applications	Temperature: Accident (°F)	Time	Norm (°F)	Time	No. Cycles	Atmosphere: Media	P(Psig)	Radiation Dose Rate: Accident (Rad/h)	Normal (Rad/h)	Nominal Dia. (in.)	Cross Section Dia. (in)	Gland Width	Dimension (in.)	Depth (in.)	Nominal Comp. (%)	Seal Length (in.)	Gland Surface Finish (rms): Top	Bot.	Side	Leakage Path	Material	Vendor & Compound	Part No.	Hardness Shore A	Normal Maintenance Period (years)	Desirable Service Life (years)	Comments or Special Problems
1a-b 2a-b	Floor Valve to Closure Valve Inner Seal	0 0	S S	170		150			Ar Ar	±15 ±15	3×10^6	400	~13.0 ~13.5	0.25 0.25									1a 1b 2a 2b	BunaN	Parker N741	—	75	5 5	5 5	
3 4	Inflatable Seals Bottom	Il Il	— —	510		190			Ar Ar	±15 ±15	3×10^6	400	~16.0 ~13.25	0.25 0.25										X	X	X	X	5 5	5 5	
5 6	Inflatable Seals Top	I I	— —	510		190			Ar Ar	±15 ±15	3×10^6	400	~16.0 ~13.25	NA										X	X	X	X	5 5	5 5	
7 8	Closer Valve to Extender	0 0	S S	190		190			Ar Ar	±15 ±15	3×10^6	400	~13.5 ~13.5	NA										EPR	Parker E692	—	75	5 5	5 5	
9 10	Backup Seal for Bottom Inflatable Seal	0 0	S S	120		≤150			Ar Ar	±15 ±15	2.0	N.1	~59.0 ~59.0	0.25 0.25										BunaN	Parker N741	—	75	5 5	5 5	
11 12	Backup Seal for Top Inflatable Seal	0 0	S S	120		~100			Ar Ar	±15 ±15	2.0	N.1	~59.0 ~59 0	0.25 0.25										BunaN	Parker N741	—	75	5 5	5 5	
13 14	Floor Valve to Closure Valve Backup Seal	0 0	S S	100		~100			Ar Ar	±15 ±15	2.0	N.1	~62 ~62	0.25 0.25										BunaN	Parker N741	—	75	5 5	5 5	Tentative design
15 16	Backup Seal for Closure Valve to Extender	0 0	S S	100		100			Ar Ar	±15 ±15	2.0	N.1	~62 ~62	0.25 0.25										BunaN	Parker N741	—	75	5 5	5 5	Tentative design
17 18	Drive Seals	0 0	S S	100		100			Ar Ar	±15 ±15	2.0	N.1	~6 ~6.5	0.25 0.25										BunaN	Parker N741	—	75	5 5	5 5	
19 20	Drive Seals	0 0	D D	100		100			Ar Ar	±15 ±15	2.0	N.1	~1.5 ~1.5	0.25 0.25										BunaN	Parker N741	—	75	5 5	5 5	

SYSTEM: CRBRP 41-2 SUBSYSTEM: CRDL/SCRS - SPENT STORAGE CELL COMPONENT:

A14

Seal No.	Seal Name	Seal Format: Type	Seal Format: Applications	Temperature (2): Accident (°F)	Temperature: Time	Temperature: Norm (°F)	Temperature: Time Yrs	Temperature: No. Cycles	Atmosphere: Media	Atmosphere: P(Psig)	Radiation Dose Rate (1): Accident (rad/hr)	Radiation Dose Rate (1): Normal (rad)	Nominal Dia. (in.)	Cross Section Dia. (in)	Gland Dimension: Width	Gland Dimension: Depth (in.)	Nominal Comp. (%)	Seal Length (in.)	Gland Surface Finish (rms): Top	Gland Surface Finish (rms): Bot.	Gland Surface Finish (rms): Side	Leakage Path	Material	Vendor & Compound	Part No.	Hardness Shore A	Normal Maintenance Period (years)	Desirable Service Life (years)	Comments or Special Problems
1	Support Flange Inner Seal	O-Ring	Static	TBD	TBD	70-240	5	TBD	Argon Air	+30 -15	600	≤6000	26.25 I.D.	0.50	0.73	0.40	13-25		32	32	32	o—o→	EPR	Parker E692	—	75	5	5	
2	Support Flange Outer Seal	O-Ring	Static	TBD	TBD	70-240	5	TBD	Argon Air	+30 -15	600	≤6000	19.50 I.D.	0.50	0.73	0.40	13-25		32	32	32	●—o→	EPR	Parker E692	—	75	5	5	
3 a-c	Storage Plug Seal (3)	O-Ring	Static	70-120	5 yrs	70-120	5	TBD	Argon Air	+30 -15	600	≤6000	17.72 I.D.	0.50	0.33	0.22	20-30		32	32	32	o—o—o→	Buna N	Parker N741	—	75	5	5	

to 5 year dose: Transfer 20 DRCL/SCRS Plugs/yr x [illegible] yr x 10 min exposure $\frac{1\ hr}{60\ min}$ x 600 rad/hr = 6000 rad

Define accident condition as such fuel assemble adjacent transfer.

SYSTEM: CRBRP 41-2 SUBSYSTEM: CRDL/SCRS - New Storage Cell COMPONENT:

A15

Seal No.	Seal Name	Seal Format: Type	Seal Format: Applications	Temperature: Accident (°F)	Temperature: Time	Temperature: Norm (°F)	Temperature: Time	Temperature: No. Cycles	Atmosphere: Media	Atmosphere: (PSI) Pressure	Radiation Dose Rate: Accident (Rad/h)	Radiation Dose Rate: Normal (Rad/h)	Nominal Dia. (in.)	Cross Section Dia. (in)	Gland Width	Dimension (in.)	Depth (in.)	Nominal Comp. (%)	Seal Length (in.)	Gland Surface Finish (rms): Top	Gland Surface Finish (rms): Bot.	Gland Surface Finish (rms): Side	Leakage Path	Material	Vendor & Compound	Part No.	Hardness Shore A	Normal Maintenance Period (years)	Desirable Service Life (years)	Comments or Special Problems
1	Support Flange Inner Seal	O-Ring	Static	70-120	5 yrs	70-120	5 yrs	TBD	Argon Air	+30 -15	NA	Nil	26.25 I.D.	.50	0.73		0.40	13-25		32	32	32	-o—o-	BunaN	Parker N741	—	75	5	5	
2	Support Flange Outer Seal	O-Ring	Static	70-120	5 yrs	70-120	5 yrs	TBD	Argon Air	+30 -15	NA	Nil	26.25 I.D.	.50	0.73		0.40	13-25		32	32	32	-o—o-	BunaN	Parker N741	—	75	5	5	

SYSTEM: 41-2 SUBSYSTEM: STORAGE FACILITIES COMPONENT: PLUGS & SLEAVES

A 16

Seal No.	Seal Name	Seal Format: Type	Seal Format: Applications	Temperature: Accident (°F)	Time	Norm (°F)	Time	No. Cycles	Atmosphere: Media	P(Psig)	Radiation Dose Rate: Accident rad/h	Normal (rad)	Nominal Dia. (in.)	Cross Section Dia. (in)	Gland Dimension: Width	Depth (in.)	Nominal Comp. (%)	Seal Length (in.)	Gland Surface Finish (rms): Top	Bot.	Side	Leakage Path	Material	Vendor & Compound	Part No.	Hardness Shore A	Normal Maintenance Period (years)	Desirable Service Life (years)	Comments or Special Problems
1	Transfer Port	0	S	150		70-100			Ar	±15	NA	N.1	0.375	0.375				93.5					Buna N	Parker	–	75	0.5	5	
2	Closure Seal	0	S	150		70-100			Ar	±15	NA		0.375	0.375				83.4						N741			0.5	5	
3	Transfer Port	Inflatable	S	150		70-100			Ar	±15	NA		23.25	0.376				72.9					X	X	X	X	2	5	
4	Isolation Seal	Inflatable	S	150		70-100			Ar	±15	NA		20.75	0.75				65.2									2	5	
5	Enclosure	0	S	150		70-100			Ar	±15	NA		119.0	0.375				374					Buna N	Parker	–	75	2	5	
6	Flange Seal	0	S	150		70-100			Ar	±15	NA		117.0	0.375				368						N741			2	5	
7	Pinion Shaft	0	S	150		70-100			Ar	±15	NA		4.109	0.139				13.3					Buna N	Parker	–	75	2	5	
8	Housing Flange	0	S	150		70-100			Ar	±15	NA		3.234	0.139				10.6						N741			2	5	
9	Pinion Shaft	0	D	150		70-100			Ar	±15	NA		0.989	0.070				3.3					Buna N	Parker	–	75	2	5	
10	Seal	0	D	150		70-100			Ar	±15	NA		0.989	0.070				3.3						N741			2	5	
11	View Glass	0	S	150		70-100			Ar	±15	NA		5.359	0.139				17.2					Buna N	Parker	–	75	2	5	
12	Seal	0	S	150		70-100			Ar	±15	NA		4.324	0.139				13.7						N741			2	5	
13	Position Ind.	0	S	150		70-100			Ar	±15	NA		4.109	0.139				13.3					Buna N	Parker	–	75	2	5	
14	Housing Flange	0	S	150		70-100			Ar	±15	NA		3.234	0.139				10.6						N741			2	5	
15	Position Ind.	0	D	150		70-100			Ar	±15	NA		0.739	0.070				2.5					Buna N	Parker	–	75	2	5	
16	Shaft Seal	0	D	150		70-100			Ar	±15	NA		0.739	0.070				2.5						N741			2	5	

SYSTEM: 41-2 SUBSYSTEM: IVTM Storage Cell COMPONENT:

A 17

Seal No.	Seal Name	Seal Format: Type	Seal Format: Applications	Temperature: Accident (°F)	Time	Norm (°F)	Time	No. Cycles	Atmosphere: Media	P(Psig)	Radiation Dose Rate: Accident (rad/h)	Normal (rad/h)	Nominal Dia. (in.)	Cross Section Dia. (in)	Gland Dimension: Width (in.)	Depth (in.)	Nominal Comp. (%)	Seal Length (in.)	Gland Surface Finish (rms): Top	Bot.	Side	Leakage Path	Material	Vendor & Compound	Part No.	Hardness Shore A	Normal Maintenance Period (years)	Desirable Service Life (years)	Comments or Special Problems
*1&2	Piston/Housing, S.F.A.	"O" Ring	Static	NA	–	50-120			Air/Argon		NA	Nil	5.75 OD	0.103	0.120	0.077	20-30%		32	32	32		Buna N	Parker N741	–	75	5	5	
*3&4	Piston/Holding Cam		Shafts rotate 120° twice/yr										0.75 OD	0.070	0.085	0.052													
*5&6	Access Chamber/ S.F.A.		Static										15.00 OD 16.00 OD	0.275	0.325	0.206													
*7&8	Window/Access Chamber												15.38 OD 16.38 OD	0.210	0.250	0.157													
*9&10	Thimble/Access Chamber												24.50 OD 25.50 OD	0.275	0.325	0.206													
*11&12	Cover, Transfer Port.												13 25 OD 14 25 OD	0.139	0.160	0.104													
*13	Transfer Port/ Access Chamber												12.00 OD	0.275	0.325	0.206													
*14a&b 15a&b	Cover, Glove Box (2 Sets)												10.75 OD 11.75 OD	0.139	0.160	0.104													
*16a&b 17a&b	Glove Box/Access Chamber (2 Sets)												9.75 OD	0.139	0.160	0.104													
*18 a&b	Glove/Glove Box (2 Sets)												9.00 OD	0.275	0.325	0.206													
*19& 20	Window/Thimble					50-120							8 00 OD 8.75 OD	0.139	0.160	0.104							Buna N	Parker N741					
21& 22	Sleeve/Thimble					50-300							9.75 OD	0.139	0.160	0.104							EPR	Parker E692					
23& 24	Thimble/Adaptor	"O" Ring				50-300							11.75 OD 13.25 OD	0.139	0.160	0.104	20-30%						EPR	Parker E692					
25& 26	IVTM/Thimble	T. Seal	Static	NA	–	50-300			Air/Argon		NA	Nil	18.00 ID	–	0.475	0.250	NA		32	32	32		EPR	Parker E692	–	75	5	5	

SYSTEM: CBRP-41-2 SUBSYSTEM: IVTM PORT PLUG STORAGE COMPONENT:

Seal No.	Seal Name	Seal Format: Type	Seal Format: Applications	Temperature: Accident (°F)	Temperature: Time	Temperature: Norm (°F)	Temperature: Time	Temperature: No. Cycles	Atmosphere: Media	Atmosphere: P(Psig)	Radiation Dose Rate *: Accident (rad/hr)	Radiation Dose Rate *: Normal (rad)	Nominal Dia. (in.)	Cross Section Dia. (in)	Gland Width	Dimension (in.)	Depth (in.)	Nominal Comp. (%)	Seal Length (in.)	Gland Surface Finish (rms): Top	Bot.	Side	Leakage Path	Material	Vendor & Compound	Part No.	Hardness Shore A	Normal Maintenance Period (years)	Desirable Service Life (years)	Comments or Special Problems
1	Support Flange Inner Seal	O-Ring	Static	TBD	TBD	70-240	5 yrs	TBD	Argon Air	+30 -15	600	≤ 6000	26.25 I.D.	0.50	0.73		0.40	13-25		32	32	32	→ -0-0-	EPR	Parker E692	—	75	5	5	
2	Support Flange Outer Seal	O-Ring	Static	TBD	TBD	70-240	5 yrs	TBD	Argon Air	+30 -15	600	≤ 6000	29.50 I.D.	0.50	0.30		0.40	13-25		32	32	32	→ -0-0-	EPR	Parker E692	—	75	5	5	
3 (a-c)	Storage Plug Seal(3)	O-Ring	Static	70-120	5 yrs	70-120	5 yrs	TBD	Argon Air	+30 -15	600	≤ 6000	17.72 I.D.	0.275	0.22		0.22	20-30		32	32	32	→ -0-0-	Buna N	Parker N741	—	75	5	5	

* 5 year dose

SYSTEM: 41 SUBSYSTEM: RFTP COMPONENT: Adaptor

Seal No.	Seal Name	Seal Format: Type	Seal Format: Applications	Temperature: Accident (°F)	Temperature: Time	Temperature: Norm (°F)	Temperature: Time	Temperature: No. Cycles	Atmosphere: Media	Atmosphere: P(Psig)	Radiation Dose Rate: Accident (rad/h)	Radiation Dose Rate: Normal (rad/h)	Nominal Dia. (in.)	Cross Section Dia. (in)	Gland Width	Dimension (in.)	Depth (in.)	Nominal Comp. (%)	Seal Length (in.)	Gland Surface Finish (rms): Top	Bot.	Side	Leakage Path	Material	Vendor & Compound	Part No.	Hardness Shore A	Normal Maintenance Period (years)	Desirable Service Life (years)	Comments or Special Problems
1	RFTP Port	O	S	-	-	-	-	-	Ar	±15	2	Nil	58	.25					~364.4				-0-	EPR	Parker E692	-	75	5	5	Used during refuling
2 3	Plug Cover	O O	S S	-	-	-	-	-	Ar Ar	±15 ±15	$3x10^6$ $3x10^6$	400 400	20.75 18.50	.25 .25					130.375 116.238				-0-0-	EPR	Parker E692	-	75	5 5	5 5	Used during refuling
4 a-c	RFTP Port Adaptor Guide Tube	I	S	775		200			Ar	±15	$3x10^6$	400	12	1/2x 7/8					~75.4				a b c -0-0-0-	X	X	X	X	5	5	Used during refuling
5 6	RFTP Rotating Guide Tube Housing	O O	S S	400 400		200 200			Ar Ar	±15 ±15	$3x10^6$ $3x10^6$	400 400	26 24	.25 .25					163.362 150.769				(1) -0-0-	EPR	Parker E692	-	75	5 5	5 5	Used during reactor Operation only
7 a-d	RFTP Rotating Guide Tube (Drive Unit)	O	S (2)	400		200			Ar	±15	$3x10^6$	400	3.0	.25					9.424				a b -0-0- c d -0-0-	EPR	Parker E692	-	75	5	5	Used at all times
8 a-b	Drive Unit	O	S	400		200			Ar	±15	$3x10^6$	400	5	.25					31.415				a b -0-0-	EPR	Parker E692	-	75	5	5	Used at all times
9 10	Inflated Seal Assembly	I I	S S	775		200			Ar Ar	±15 ±15	$3x10^6$	400	14 12.75	.25 .25					57.964 80.110				-0-0-	X	X	X	X	5 5	5 5	Used during refuling
11 12	Nozzel	O O	S S	350		150			Ar Ar	±15 ±15	$2x10^6$ $2s10^6$	Nil Nil	30 28.5	.25 .25					188.495 179.070				(1) -0-0-	EPR	Parker E692	-		5 5	5 5	Used at all times

* 5 yr dose

(1) Must leak past Port Plug first.

It has been assumed Port Seals gone

~~(2) Semi Dynamic Seal~~

SYSTEM 41 SUBSYSTEM: EVST COMPONENT: Storage Vessel

Seal No.	Seal Name	Seal Format: Type	Seal Format: Applications	Service Conditions: Temperature: Accident (°F) (3)	Time	Norm (°F)	Time	No. Cycles	Atmosphere: Media	P(Psig)	Radiation Dose Rate * (1): Accident (rad/h)	Normal (rad)	Nominal Dia (ID) (in.)	Cross Section Dia. (in)	Gland Width
1	Outside Storage Vessel	"O"-Ring	Static	3		125			Argon	±15	1.5×10^4	8×10^5	276		
2	Inside Storage Vessel	"O"-Ring	Static	3		125			Argon	±15	1.5×10^4	8×10^5	273		
3	Outside Closure Head	"O"-Ring	Static	3		120			Argon	±15	1.5×10^4	8×10^5	220.25		
4	Inside Closure Head	"O"-Ring	Static	3		120			Argon	±15	1.5×10^4	8×10^5	217.25		

Seal No.	Seal Dimensions: Dimension (in.)	Depth (in.)	Nominal Comp. (%)	Seal Length (in.)	Gland Surface Finish (rms): Top	Bot.	Side	Leakage Path	Seal Selection: Material	Vendor & Compound	Part No.	Hardness Shore A	Normal Maintenance Period (years)	Desirable Service Life (years)	Comments or Special Problems
1								—o—o— inside outside	Metal	–	–	–	5	30 yrs	Face Seals
2								—o—o—	Metal	–	–	–	5	30 yrs	Face Seals
3								—o—o—	Metal	–	–	–	5	30 yrs	Face Seals
4								—o—o—	Metal	–	–	–	5	30 yrs	Face Seals

*5 year Dose

(1) EVST Cover Gas Radiation Level plus dose from Na pool and stored fuel elements = 11 rad/hr continuous (5 yr) There is also the transient dose from passing fuel elements

(2) Prints available, but not latest drawing
Latest drawing No. R-N099999725

(3) Stuck Fuel Assembly

(4) For transient passing fuel element radiation dose is given as average, assume speed 16 ft/min ~total influence of fuel 1 min (normal condition)

SYSTEM 41 SUBSYSTEM EVST COMPONENT: Turntable Drive

Seal No.	Seal Name	Seal Format: Type	Seal Format: Applications	Service Conditions: Temperature (1): Accident (°F)	Time	Norm (°F)	Time	No. Cycles	Atmosphere: Media	P(Psig)	Radiation Dose Rate: Accident (rad/h)	Normal (rad)*	Nominal Dia. (in.)	Cross Section Dia. (in)	Gland Width
1. a-b	Shaft (2 Shafts) Seal (4 Seals)	"U" Cup	Dynamic	170		170			Ar	±15	$\leq 1.5 \times 10^4$	8×10^5	8.000		
2 a-b	Housing Seal	"O" Ring	Static	170		170			Ar	±15	$\leq 1.5 \times 10^4$	8×10^5	16.500		

Seal No.	Seal Dimensions: Dimension (in.)	Depth (in.)	Nominal Comp. (%)	Seal Length (in.)	Gland Surface Finish (rms): Top	Bot.	Side	Leakage Path	Seal Selection: Material	Vendor & Compound	Part No.	Hardness Shore A	Normal Maintenance Period (years)	Desirable Service Life (years)	Comments or Special Problems
1. a-b								—o—o—	EPR	Parker E692	-	75	5 5	>5 years	Dual Buffered Seal
2 a-b								—o—o—	EPR	Parker E692	-	75	5 5	>5 years	Piston Groove Type

*5 Year Dose

(1) Stuck Fuel Assembly Adjacent

A 22

SYSTEM: 41 SUBSYSTEM: EVST COMPONENT: Access Plug**

Seal No.	Seal Name	Seal Format: Type	Seal Format: Applications	Service Conditions – Temperature: Accident (°F)	Time	Norm (°F)	Time	No. Cycles	Atmosphere: Media	P(Psig)	Radiation Dose Rate: Accident (rad/h)	Normal (rad)*	Nominal Dia. (in.)	Cross Section Dia. (in)	Gland Width	Seal Dimensions – Dimension (in.)	Depth (in.)	Nominal Comp. (%)	Seal Length (in.)	Gland Surface Finish (rms): Top	Bot.	Side	Leakage Path	Seal Selection: Material	Vendor & Compound	Part No.	Hardness Shore A	Normal Maintenance Period (years)	Desirable Service Life (years)	Comments or Special Problems
1 a-b ~~(9 plug)~~	Access Port Plug	"O" Ring	Static	NA		≤ 187 max.			Argon		NA	$5x10^5$	9.475	0.275									-o-o-	EPR	Parker E692	-	75		75	Piston Groove Type

* ~~5 Year Dose~~

** 9 Plugs Total {7 Plugs Inplace, 2 Adaptors}

A 23

SYSTEM: 41 SUBSYSTEM: EVST COMPONENT: FLOOR VALVE ADAPTOR

Seal No.	Seal Name	Seal Format: Type	Seal Format: Applications	Service Conditions – (1) Temperature: Accident (°F)	Time	Norm (°F)(2)	Time	No. Cycles	Atmosphere: Media	P(Psig)	Radiation Dose Rate: Accident (rad/h)	Normal (rad)	Nominal Dia.(ID) (in.)	Cross Section Dia. (in)	Gland Width	Seal Dimensions – Dimension (in.)	Depth (in.)	Nominal Comp. (%)	Seal Length (in.)	Gland Surface Finish (rms): Top	Bot.	Side	Leakage Path	Seal Selection: Material	Vendor & Compound	Part No.	Hardness Shore A	Normal Maintenance Period (years)	Desirable Service Life (years)	Comments or Special Problems
1, a-b	Access Adaptor Lower Seals (2 seals)	O-Ring	Static	500		200			Argon		$3x10^6$	$6x10^7$ total ~~dose for~~ 5 years	13.475	0.275									-o-o-	EPR	Parker E692	456	75		5 yrs	Piston groove type
	Flange Seals (inner)	O-Ring	Static										~16.5	0.275										EPR	Parker E692	460	75			
	Flange Seal (outer)												~18.5	0.275										EPR	Parker E692	460	75			

SYSTEM: 41 SUBSYSTEM: EVST COMPONENT: Inspection Plugs

Seal No.	Seal Name	Seal Format: Type	Seal Format: Applications	Service Conditions: Temperature: Accident (°F)(2)	Time	Norm (°F)(1)	Time	No. Cycles	Atmosphere: Media	P(Psig)	Radiation Dose Rate: Accident (rad/h)	Normal (rad)*	Nominal Dia. (in.)	Cross Section Dia. (in)	Gland Width	Seal Dimensions: Dimension (in.)	Depth (in.)	Nominal Comp. (%)	Seal Length (in.)	Gland Surface Finish (rms): Top	Bot.	Side	Leakage Path	Seal Selection: Material	Vendor & Compound	Part No.	Hardness Shore A	Normal Maintenance Period (years)	Desirable Service Life (years)	Comments or Special Problems
A a-b	Inner Annulus (4 plugs) (8 seals)	"0"-Ring	Static	②		150			Argon		1.5 x 10^4	8 x 10^5	3.25	.210									-0-0-	EPR	Parker E692	–	75		>5 yrs	Piston Groove Type
B a-b	Dip Seal Inspection					150					1.5 x 10^4	8 x 10^5	2.25	.210									-0-0-			–				
C a-b	Dip Seal Inspection (Head)					160					1.5 x 10^4	8 x 10^5	2.25	.210									-0-0-			–				
D a-b	Outer Annulus (4 plugs) (8 seals) (Head)					160					1.5 x 10^4	8 x 10^5	6.50	.275									-0-0-			–				
E a-b	Dip Seal (Head) Inspection					150					1.5 x 10^4	8 x 10^5	6.50	.275									-0-0-			–				
F a-b	Outer Annulus (4 plugs) (8 seals) (T/T)					216					≤ 20	5 x 10^5	3.25	.210									-0-0-			–				
G a-b	Dip (T/T) Seal Inspection					216					≤ 20	5 x 10^5	2.25	.210									-0-0-			–				
H a-b	Dip Seal Inspection (S/V)	"0"-Ring	Static	②		145			Argon		1.5 x 10^3	5 x 10^5	2.25	.210									-0-0-	EPR	Parker E692	–	75		>5 yrs	Piston Groove Type

*5 Year Dose

(1) ~~Sodium Pool 625°F~~
(2) No cooling is defined as accident condition Analysis not performed yet

SYSTEM: 41 SUBSYSTEM: FHC COMPONENT: CEILING

Seal No.	Seal Name	Seal Format: Type	Seal Format: Applications	Service Conditions: Temperature (1): Accident (°F)	Time	Norm (°F)(2)	Time	No. Cycles	Atmosphere: Media	P(Psig)	Radiation Dose Rate (1): Accident (rad/h)	Normal (rad)	Nominal Dia. (ID) (in.)	Cross Section Dia. (in)	Gland Width	Seal Dimensions: Dimension (in.)	Depth (in.)	Nominal Comp. (%)	Seal Length (in.)	Gland Surface Finish (rms): Top	Bot.	Side	Leakage Path	Seal Selection: Material	Vendor & Compound	Part No.	Hardness Shore A	Normal Maintenance Period (years)	Desirable Service Life (years)	Comments or Special Problems
1 2	Examination Station Access Port	0 0	Static Static	NA NA		100 100			Ar Ar	~1	NA	Nil	~10 5 ~12.0		0.208		0.110			32	32	63	-0-0-	Buna N	Parker N741	2-275 2-278	75	5	5	
3 4	Spent Fuel Loading Access Port	0 0	Static Static	NA NA		100 100			Ar Ar	~1	NA	Nil	~10 5 ~12 0		0.208		0.110			32	32	63	-0-0-	Buna N	Parker N741	2-275 2-278	75	5	5	
5 6	Spent Fuel Transfer Port Cover Plate	0 0	Static Static	695 695		105 105			Ar Ar	~1	1x10^6	6x10^6	15.525 17.005	0.275 0.275	0.375		0.227	15-20		32	32	63	-0-0- -0-0-	EPR	Parker E692	2-459 2-462	75	5	5	
7 8	Spent Fuel Port, ShieldPlug	0 0	Static Static	NA Removed		100 100			Ar Ar	~1	NA	Nil	9.512 9.512	0 139			0.112	16-23		32	32	63	-0-0	Buna N	Parker N741	2-271 2-271	75	5	5	
9 10	Port to Floor Valve Adapter										NA	Nil											X	X	X	X	X			Not designed at this time
11 12	Main Cover Plate	0	Static	NA		100 100			Ar Ar	~1 ~1	NA	Nil	80.390 81 761	0 210 0.210	0 173 0.173		0.180 0.180		253 21 257.53	16	16	64	-0-0-	Buna N	Parker N741	–	75	5 5	5 5	Dovetail grooves
13 14	Inflatable Seals	IP	Static	NA		200 200			Ar Ar	~1 ~1	500	2500	~30 ~31	NA NA	NA		NA						-0-0-	X	X	X	X			
15 16	Seal Ring	0	Static	NA		100 100			Ar Ar	~1 ~1	NA	Nil	33.261 34.580	0.210 0.210	0.173 0.173	0.180 0.180			105.16 109.30				-0-0-	Buna N	Parker N741	–	75	5 5	5 5	Dovetail groove
17 18	28" Plug	0	Static	NA		100 100			Ar Ar	~1 ~1	NA	Nil	28.702 30 167	0.210 0 210	0.173 0.173	0.180 0.180			90.83 95.43				-0-0-	Buna N	Parker N741	–	75	5 5	5 5	Dovetail groove
19 20	12" Plug	0	Static	NA		150 150			Ar Ar	~1 ~1	NA	Nil	12.00 12.829	0.210 0.210	0.173 0.173	0.180 0.180			38.24 42.36				-0-0-	Buna N	Parker N741	–	75	5 5	5 5	Dovetail groove
21 a-b	Drive Shaft	0	D	NA		100			Ar	~1	NA	Nil	1.607	0.370	0.285	0.370							-0-0-	Buna N	Parker N741	2-319	75	5	5	
22 23	Drive Support Cover	0 0	Static Static	NA		100 100			Ar Ar	~1 ~1	NA	Nil	18.702 20.014	0.210 0.210	0.173 0.173	0.180 0.180							-0-0-	Buna N	Parker N741	–	75			
24 25	Drive Cavity Cover			NA		100 100					NA	Nil	Unique Unique						94.93 90.46				-0-0-	Buna N	Parker N741	–	75			

(1) 5 year radiation dose

SYSTEM: 41-2 SUBSYSTEM: AHM COMPONENT: Grapple Drive (Sheet 1 of 2)

Seal No.	Seal Name	Seal Format: Type	Seal Format: Applications	Service Conditions: Temperature: Accident (°F)	Time	Norm (°F)	Time	No. Cycles	Atmosphere: Media	P(Psig)	Radiation Dose Rate: Accident (rad/h)	Normal (rad)	Nominal Dia. (in.)	Cross Section Dia. (in)	Gland Width	Seal Dimensions: Dimension (in.)	Depth (in.)	Nominal Comp. (%)	Seal Length (in.)	Gland Surface Finish (rms): Top	Bot.	Side	Leakage Path	Seal Selection: Material	Vendor & Compound	Part No.	Hardness Shore A	Normal Maintenance Period (years)	Desirable Service Life (years)	Comments or Special Problems
1	Housing Lid Outer	O-Ring	Static	NA		70 to 100 Max			Ar	±15	NA	6×10^5	217.0 in long	0.275					212.5					BunaN	Parker N741	–	75	5	5	
2	Housing Lid Inner	O-Ring	Static			70 to 100 Max			Ar	±15	NA	6×10^5	212.5 in long	0.275					217.0							–				
3	Drive Shaft Right Side Inner	O-Ring	Dynamic			70 to 100 Max			Ar	±15	NA	6×10^5	3.25	0.21					10.21							–				
4	Drive Shaft Left Side Outer	O-Ring	Dynamic			70 to 100 Max			Ar	±15	NA	6×10^5	3.25	0.21					10.21							–				
5	Drive Shaft Right Side Outer	O-Ring	Dynamic			70 to 100 Max			Ar	±15	NA	6×10^5	3.25	0.21					10.21							–				
6	Drive Shaft Left Side Inner	O-Ring	Dynamic			70 to 100 Max			Ar	±15	NA	6×10^5	3.25	0.21					10.21							–				
7	Drive Shaft Collar Right Inner	O-Ring	Static			70 to 100 Max			Ar	±15	NA	6×10^5	6.50	0.21					20.42							–				
8	Drive Shaft Collar Left Inner	O-Ring	Static			70 to 100 Max			Ar	±15	NA	6×10^5	6.50	0.21					20.42							–				
9	Drive Shaft Collar Right Outer	O-Ring	Static			70 to 100 Max			Ar	±15	NA	6×10^5	6.50	0.21					20.42							–				
10	Drive Shaft Collar left Outer	O-Ring	Static			70 to 100 Max			Ar	±15	NA	6×10^5	6.50	0.21					20.42							–				
11	Grapple Shaft Actuate Inner	O-Ring	Dynamic			70 to 100 Max			Ar	±15	NA	6×10^5	2.00	0.21					6.28							–				
12	Grapple Shaft Actuate Outer	O-Ring	Dynamic			70 to 100 Max			Ar	±15	NA	6×10^5	2.00	0.21					6.28							–				
13	Grapple Shaft Collar Inner	O-Ring	Static			70 to 100 Max			Ar	±15	NA	6×10^5	4.00	0.21					13.74							–				
14	Grapple Shaft Collar Outer	O-Ring	Static	NA		70 to 100 Max			Ar	±15	NA*	6×10^5	4.32	0.21					13.74					BunaN	Parker N741	–	75	5	5	* 5 yr dose.

SYSTEM: 41-2 SUBSYSTEM: AHM COMPONENT: GRAPPLE DRIVE (Sheet 2 of 2)

Seal No.	Seal Name	Seal Format: Type	Seal Format: Applications	Service Conditions: Temperature: Accident (°F)	Time	Norm (°F)	Time	No. Cycles	Atmosphere: Media	P(Psig)	Radiation Dose Rate: Accident (rad/h)	Normal (rad)	Nominal Dia. (in.)	Cross Section Dia. (in)	Gland Width	Seal Dimensions: Dimension (in.)	Depth (in.)	Nominal Comp. (%)	Seal Length (in.)	Gland Surface Finish (rms): Top	Bot.	Side	Leakage Path	Seal Selection: Material	Vendor & Compound	Part No.	Hardness Shore A	Normal Maintenance Period (years)	Desirable Service Life (years)	Comments or Special Problems
15.	Encoder Shaft Inner	O-Ring	Dynamic	NA		70 to 100 max.			Ar	±15	NA	$\leq 6 \times 10^5$ rad 5 yr	0.375 Dia.	0.21					1.17					BunaN	Parker N741	–	75	5	5	
16.	Encoder Shaft Outer		Dynamic										0.375 Dia.	0.21					1.17							–				
17.	Encoder Housing Inner		Static										2.00 Dia.	0.21					6.28							–				
18.	Encoder Housing Outer		Static										2.00 Dia.	0.21					6.28							–				
19.	Hydraset Shaft Inner		Dynamic										2.00 Dia.	0.21					6.28							–				
20	Hydraset Shaft Outer		Dynamic										2.00 Dia.	0.21					6.28							–				
21	Hydraset Housing Inner		Static										10.00 Dia.	0.21					32.98							–				
22.	Hydraset Housing Outer		Static									$\leq 6 \times 10^5$ rad 5 yr	10.50 Dia	0.21					32.98							–				
23.	Mom Port 11 required	O-Ring	Static	NA		70 to 100 max.			Ar	±15	NA	1.5×10^5	0.62 Dia.	0.06					21.56					BunaN	Parker N741	–	75	5	5	
	* 5 yr dose																													

SYSTEM: 41-2 SUBSYSTEM: AHM COMPONENT: Chain Storage Tube

Seal No.	Seal Name	Seal Format: Type	Seal Format: Applications	Temperature: Accident (°F)	Time	Norm (°F)	Time	No. Cycles	Atmosphere: Media	P(Psig)	Radiation Dose Rate: Accident (rad/h)	Normal (rad)*	Nominal Dia. (in.)	Cross Section Dia. (in)	Gland Width	Seal Dimensions: Dimension (in.)	Depth (in.)	Nominal Comp. (%)	Seal Length (in.)	Gland Surface Finish (rms): Top	Bot.	Side	Leakage Path	Seal Selection: Material	Vendor & Compound	Part No.	Hardness Shore A	Normal Maintenance Period (years)	Desirable Service Life (years)	Comments or Special Problems
24	Storage Tube to Drive Housing Inner	O-Ring	Static	NA		70 to 100 Max			Ar	±15	≤1.42 x 10^4	≤3 x 10^4	16.38	0.275					51.44					BanaN	Parker N741	–	75	5	5	
25	Storage Tube to Drive Housing Outer	O-Ring	Static	NA		70 to 100 Max			Ar	±15	≤1.42 x 10^4	≤3 x 10^4	17.38	0.275					54.58					BanaN	Parker N741	–	75	5	5	
26	Storage Tube Center Flange Inner	O-Ring	Static	NA		70 to 100 Max			Ar	±15	≤1.42 x 10^4	≤3 x 10^4	16.38	0.275					51.44					BanaN	Parker N741	–	75	5	5	
27	Storage Tube Center Flange Outer	O-Ring	Static	NA		70 to 100 Max			Ar	±15	≤1.42 x 10^4	≤3 x 10^4	17.38	0.275					54.58					BanaN	Parker N741	–	75	5	5	
28	Storage Tube Bottom Flange Inner	O-Ring	Static	NA		70 to 100 Max			Ar	±15	≤1.42 x 10^4	≤3 x 10^4	16.38	0.275					51.44					BanaN	Parker N741	–	75	5	5	
29	Storage Tube	O-Ring	Static	NA		70 to 100 Max			Ar	±15	≤1.42 x 10^4	≤3 x 10^4	17.38	0.275					54.58					BanaN	Parker N741	–	75	5	5	
30	Mom Ports 4 Required	O-Ring	Static	NA		70 to 100 Max			Ar	±15	≤1.42 x 10^4	≤3 x 10^4	.62	.09					7.84					BanaN	Parker N741	–	75	5	5	

*5 Year Dose

SYSTEM: 41-2 SUBSYSTEM: AHM COMPONENT: Cask Containment Barrel

Seal No.	Seal Name	Seal Format: Type	Seal Format: Applications	Temperature: Accident (°F)	Time	Norm (°F)	Time	No. Cycles	Atmosphere: Media	P(Psig)	Radiation Dose Rate: Accident (rad/h)	Normal (rad)*	Nominal Dia. (in.)	Cross Section Dia. (in)	Gland Width	Seal Dimensions: Dimension (in.)	Depth (in.)	Nominal Comp. (%)	Seal Length (in.)	Gland Surface Finish (rms): Top	Bot.	Side	Leakage Path	Seal Selection: Material	Vendor & Compound	Part No.	Hardness Shore A	Normal Maintenance Period (years)	Desirable Service Life (years)	Comments or Special Problems
31	Barrel to Drive Housing Collar	T-Ring		NA		70 to 100 Max			Ar	±15	NA	3 x 10^5	14.00						43.98					BunaN	Parker N741	–	75	5	5	
32	Barrel to Drive Housing Collar	T-Ring		NA		70 to 100 Max			Ar	±15	NA	3 x 10^5	14.00						43.98					BunaN	Parker N741	–	75	5	5	
33	Barrel to Drive Housing Collar	T-Ring		NA		70 to 100 Max			Ar	±15	NA	3 x 10^5	14.00						43.98					BunaN	Parker N741	–	75	5	5	
34	Mom Port 2 Required	O-Ring		NA		70 to 100 Max			Ar	±15	NA	3 x 10^5	.62	.09					3.9					BunaN	Parker N741	–	75	5	5	

*5 Year Dose

SYSTEM: 41-2 SUBSYSTEM: AHM COMPONENT: Closure Valve Sheet 1 of 2

Seal No.	Seal Name	Seal Format: Type	Seal Format: Applications	Service Conditions: Temperature: Accident (°F)	Time	Norm (°F)	Time	No. Cycles	Atmosphere: Media	P(Psig)	Radiation Dose Rate: Accident (rad/h)	Normal (rad)*	Nominal Dia. (in.)	Cross Section Dia. (in)	Gland Width	Seal Dimensions: Dimension (in.)	Depth (in.)	Nominal Comp. (%)	Seal Length (in.)	Gland Surface Finish (rms): Top	Bot.	Side	Leakage Path	Seal Selection: Material	Vendor & Compound	Part No.	Hardness Shore A	Normal Maintenance Period (years)	Desirable Service Life (years)	Comments or Special Problems
35.	Inflatable Upper	Inflatable	–	≤250		70 to 120 max			Ar Na vapor	±15	NA	1×10^7	54.00						169.6							–		5	5	Tentative Design
36.	Inflatable Inner Bottom	Inflatable	–						Ar Na vapor			$\leq 1 \times 10^7$	23.50						73.82							–				Tentative Design
37.	Inflatable Outer Bottom	Inflatable	–						Ar Na vapor			$\leq 1 \times 10^7$	25.50						80.11							–				Tentative Design
38.	Valve to Containment Barrel Outer	O-Ring	Static						Ar			$\leq 1 \times 10^7$	26.50	0.275					83.25					Buna N	Parker N741	–	75			
39.	Valve to Containment Barrel Inner	O-Ring	Static						Ar			$\leq 1 \times 10^7$	24.50	0.275					76.76							–				
40.	Valve to Extender Outer	O-Ring	Static						Ar			—	26.50	0.275					83.25							–				
41.	Valve to Extender Inner	O-Ring	Static						Ar			—	24.50	0.275					76.76							–				
42.	Valve Flange to Body Top Inner	O-Ring	Static						Ar			3×10^5	61.50	0.275					193.2							–				
43.	Valve Flange to Body Top Outer	O-Ring	Static						Ar			3×10^5	63.50	0.275					199.49							–				
44.	Valve Flange to Body Bottom Inner	O-Ring	Static						Ar			3×10^5	61.50	0.275					193.2							–				
45.	Valve Flange to Body Bottom Outer	O-Ring	Static						Ar			3×10^5	63.50	0.275					199.49							–				
46.	View Port Inner	O-Ring	Static						Ar			3×10^5	10.75	0.139					33.77							–				
47.	View Port Outer	O-Ring	Static	≤250		70 to 120 max			Ar	±15	NA	3×10^5	12.25	0.139					38.48					Buna N	Parker N741	–	75	5	5	
	*5 Yr dose																													

SYSTEM: 41-2 SUBSYSTEM: AHM COMPONENT: Closure Valve Sheet 2 of 2

Seal No.	Seal Name	Seal Format: Type	Seal Format: Applications	Service Conditions: Temperature: Accident (°F)	Time	Norm (°F)	Time	No. Cycles	Atmosphere: Media	P(Psig)	Radiation Dose Rate: Accident (rad/h)	Normal (rad)*	Nominal Dia. (in.)	Cross Section Dia. (in)	Gland Width	Seal Dimensions: Dimension (in.)	Depth (in.)	Nominal Comp. (%)	Seal Length (in.)	Gland Surface Finish (rms): Top	Bot.	Side	Leakage Path	Seal Selection: Material	Vendor & Compound	Part No.	Hardness Shore A	Normal Maintenance Period (years)	Desirable Service Life (years)	Comments or Special Problems
48.	Pinion Gear Collar Inner	O-Ring	Static	≤250		70 to 120 max			Ar	±15	NA	3×10^5	6.50	0.139					20.42					Buna N	Parker N741	–	75	5	5	
49	Pinion Gear Collar Outer	O-Ring	Static						Ar			3×10^5	8.00	0.139					25.13							–				
50.	Pinion Gear Stem Outer	O-Ring	Dynamic						Ar			3×10^5	1.50	0.139					4.71							–				
51.	Pinion Gear Stem Inner	O-Ring	Dynamic						Ar			3×10^5	1.50	0.139					4.71							–				
52.	Mom Port 10 Req'd	O-Ring	Static	≤250		70 to 120 max			Ar	±15	NA	1×10^5	0.62	0.09					19.6					Buna N	Parker N741	–	75	5	5	
	*5 Yr dose																													

SYSTEM: 41-2 SUBSYSTEM: AHM COMPONENT: Extender

Seal No.	Seal Name	Seal Format: Type	Seal Format: Applications	Service Conditions — Temperature: Accident (°F)	Time	Norm (°F)	Time	No. Cycles	Atmosphere: Media	P(Psig)	Radiation Dose Rate: Accident (Rad/h)	Normal (rad)*	Nominal Dia. (in.)	Cross Section Dia. (in)	Gland Width
53	Inflatable	Inflatable	–	≤250		70 to 120 Max			Ar Na VAPOR	±15	NA	$\leq 1 \times 10^7$	25.25		
54	Inflatable	Inflatable	–	≤250		70 to 120 Max			Ar Na VAPOR	±15	NA	$\leq 1 \times 10^7$	25.25		
55	Extender Flange to Body Top Inner	O-Ring	Static	≤250		70 to 120 Max			Ar	±15	NA	$\leq 1 \times 10^7$	23.50	.275	
56	Extender Flange to Body Top Outer	O-Ring	Static	≤250		70 to 120 Max			Ar	±15	NA	$\leq 1 \times 10^7$	24.75	.275	
57	Extender Flange to Body Bottom Inner	O-Ring	Static	≤250		70 to 120 Max			Ar	±15	NA	$\leq 1 \times 10^7$	23.50	.275	
58	Extender Flange to Body Bottom Outer	O-Ring	Static	≤250		70 to 120 Max			Ar	±15	NA	$\leq 1 \times 10^7$	24.75	.275	
59	Extender Body to Sleeve	O-Ring	Static	≤250		70 to 120 Max			Ar	±15	NA	$\leq 3 \times 10^5$	27.75	.275	
60	Mom Port 10 Required	O-Ring	Static	≤250		70 to 120 Max			Ar	±15	NA	$\leq 1 \times 10^5$	.62	.09	

Seal No.	Seal Dimensions — Gland Dimension (in.)	Depth (in.)	Nominal Comp. (%)	Seal Length (in.)	Gland Surface Finish (rms): Top	Bot.	Side	Leakage Path	Seal Selection — Material	Vendor & Compound	Part No.	Hardness Shore A	Normal Maintenance Period (years)	Desirable Service Life (years)	Comments or Special Problems
53				79.32							–		5	5	Tenitive Design
54				79.32							–				Tenitive Design
55				73.82					BunaN	Parker N741	–	75			
56				77.75					BunaN		–				
57				73.82					BunaN		–				
58				77.75					BunaN		–				
59				87.17					BunaN		–				
60				19 6					BunaN	Parker N741	–	75	5	5	

*5 Year Dose